352 AMAZING IMAGES & CUTAWAYS INSIDE

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS™

SCIENCE | ENVIRONMENT | TECHNOLOGY | TRANSPORT | HISTORY | SPACE

INSIDE

SNIFFER DOGS
THE NEW WAYS THAT DOGS CAN SAVE LIVES

SUPER COMPUTERS
The tech that's more powerful than 700,000 iPads

LASER EYE SURGERY
How this miracle op can save your sight

MEGA WATERFALLS
Niagara Falls can fill an Olympic pool every second

METEORITES
Learn about the cosmic rocks that wiped out the dinosaurs

DIVING DEEPER THAN EVEREST

OCEAN HUNTERS

REVEALED: THE EXTREME DEEP-SEA SUBS EXPLORING THE PLANET'S FINAL FRONTIER

SCIENCE OF EXPLOSIONS
THE CRAZY CHEMISTRY BEHIND BLOWING STUFF UP

+ LEARN ABOUT
- ANTENNAS
- GLOW ROADS
- THE CELTS
- ARMY TANKS
- FIRST CINEMAS
- SNAKE SKIN
- CURING DEAFNESS
- ROMAN MONEY
- HYDROPONICS
- MITOCHONDRIA
- MARS HOPPER
- COURT JESTERS

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ISSUE 62

WELCOME

The magazine that feeds minds!

Page 24
We go inside fireworks, volcanoes and other explosive materials to see what exactly makes them go kaboom

The thought of being crammed into a capsule and sent to the deepest part of Earth's oceans leaves me gasping for air. Yet film-maker James Cameron spent seven years developing a submersible to do just that. Dropping 152 metres (500 feet) per minute, he passed the depth of the Titanic easily – the ship that made him billions at the box office with his 1997 blockbuster.

Funnily enough,watching that movie takes almost as long as it took Cameron to sink to the bottom of the Mariana Trench. A mile deeper than Mount Everest, he went where seven billion people on the planet couldn't, overcoming claustrophobic conditions and crushing pressure that actually caused the sub to shrink.

The descent has been called "the ultimate test of man and machine" and you can discover how this feat of engineering was achieved and more in our in-depth feature. We also go into space to hunt for dark matter and log on to computers more powerful than 700,000 iPads. If that won't blow your mind, then our article on the science of explosions certainly will.

Jodie

Jodie Tyley
Deputy Editor

Meet the team...

Moe
Designer
The Celts were a fascinating civilisation and a lot more advanced than you would think, as you can see on page 72.

Erlingur
Production Editor
I struggle with the speed of a *Call Of Duty* video game, so reading about the fastest supercomputers was outright dizzying.

Jamie
Staff Writer
All kids love explosions and being a big kid at heart I loved finding out what goes boom the loudest. Check it out on page 24.

Jackie
Research Editor
This month's space feature aims to shine some light on the mysterious dark matter that fills our universe.

Hannah
Assistant Designer
I found it reassuring we wont be facing a real-life Armageddon for a while yet due to NASA's meteor warning systems.

Jack
Staff Writer
The plans for another Mars mission are very, very exciting indeed. Hop on over to page 49 for a spacecraft with a twist!

What's in store

Check out just a small selection of the questions answered in this issue of How It Works...

Have scientists found a cure for deafness? **Page 34**

Why are snakes covered in scales? **Page 56**

Are solar-powered planes taking off? **Page 20**

How do inflatable concert halls work? **Page 70**

How do meteorites survive a fall from space? **Page 50**

What's the story behind the ferocious Celts? **Page 72**

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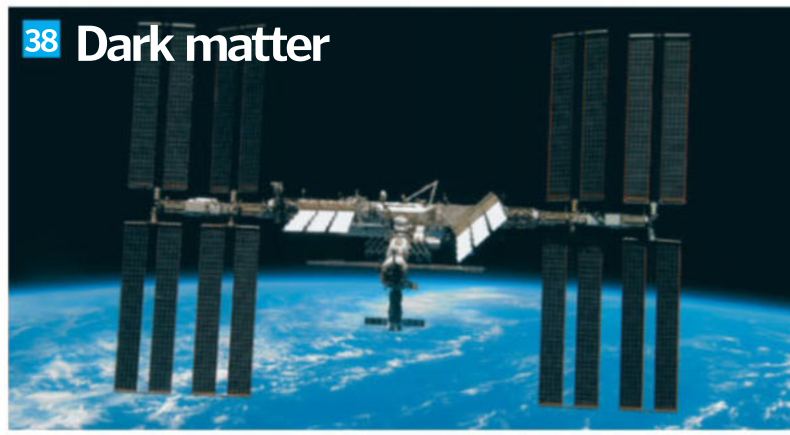
CONTENTS

12 OCEAN HUNTERS

Revealing the deep-sea subs exploring the planet's final frontier



Meet the experts...

Laura Mears
Brain debunked
Have you ever been described as a left or right-brained thinker? This month, Laura settles the matter, once and for all. She also recommends some handy brain exercises to keep your mind sharp this summer.

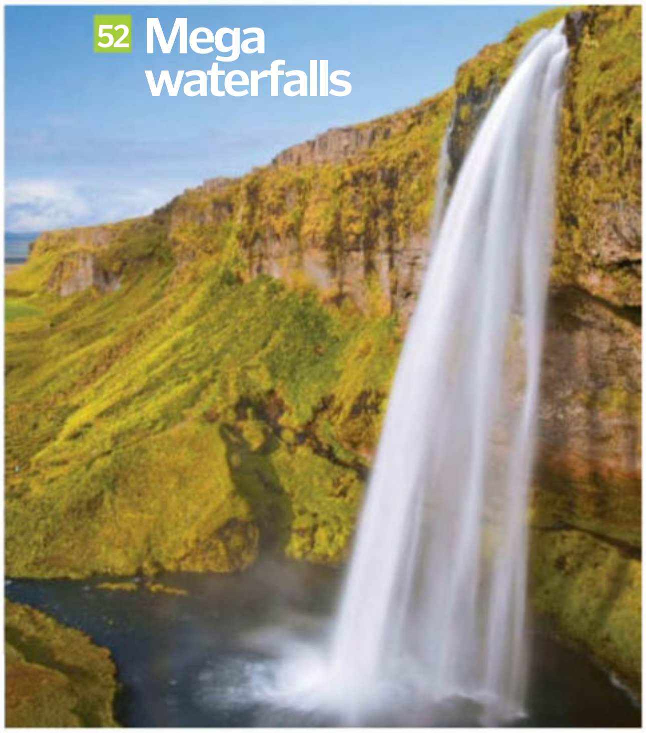
Luis Villazon
Supercomputers
Luis' degree in real-time computing was called upon to explain the most complex computers on the planet. They're more powerful than 700,000 iPads, but are they a match for the human brain?

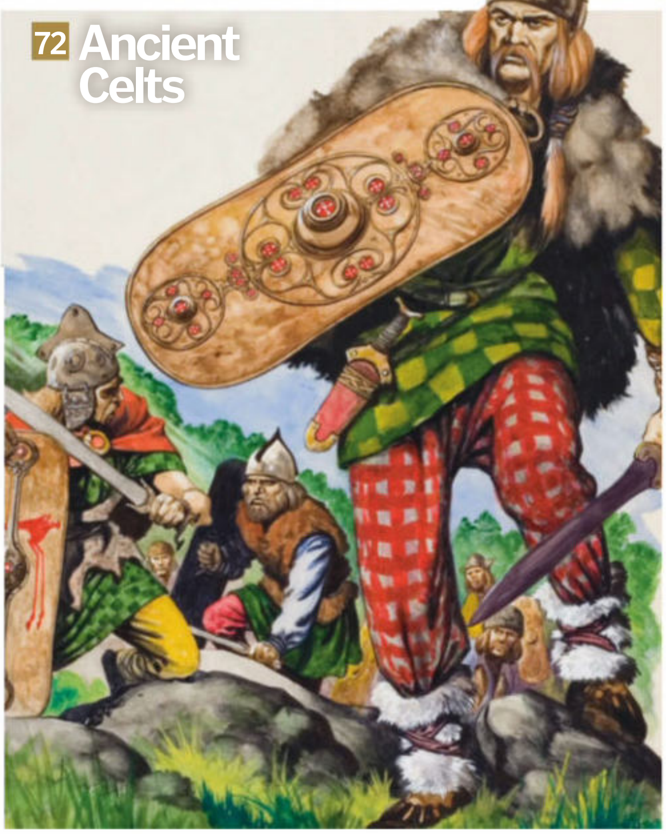
Vivienne Raper
Mega-waterfalls
Ever wondered how Niagara Falls came to be? Find out all you need to know about these natural wonders in Vivienne's guide to the biggest and best waterfalls on the planet.

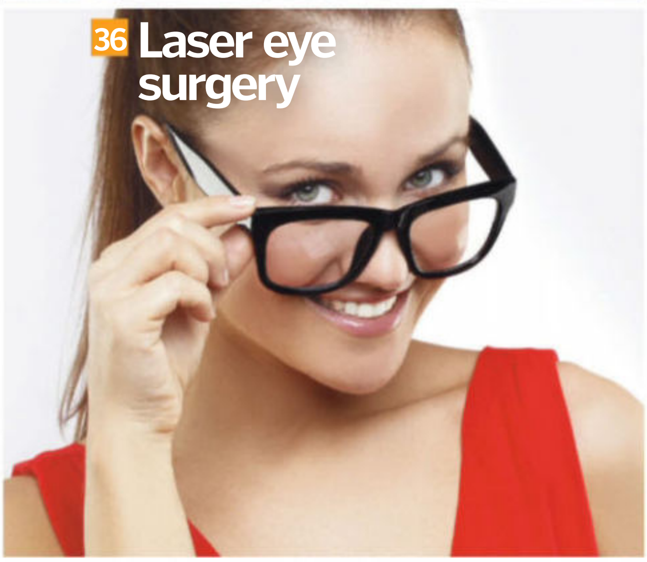
Michael Scott
Hydroponics
It's possible to grow plants using mineral nutrient solutions, in water, with absolutely no soil whatsoever. Find out how in Michael's article on hydroponics.

Aneel Bhangu
Mitochondria
This issue, Aneel delves into the microscopic organelles that produce all the energy our cells need to function. He reveals exactly how mitcochondria work.

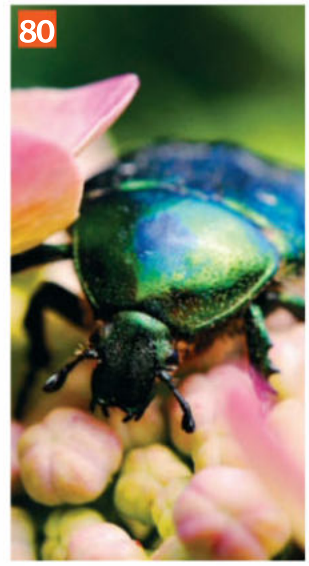
Are rats really able to regret their bad decisions?
Find out on pg 11







REGULARS



GLOBAL EYE

Showcasing the incredible world we live in

The exterior of the Bloodhound SSC

"It's aiming to reach this eye-watering speed target in as little as 55 seconds"

Inside the 1,000mph car

The Bloodhound aims to be Earth's fastest car

This is what the dashboard looks like on a 1,609-kilometre-(1,000-mile)-per-hour car. The vehicle is known as the Bloodhound and it is bidding to become the first car in history to break the 1,000-mile-per-hour barrier. It will line up for its run in South Africa in 2015 and it's aiming to reach this eye-watering speed target in as little as 55 seconds, or about the time it takes you to read this short text.

The windscreen is as tough as those used in fighter aircraft to protect from the immense air resistance and as you can see, there are an astonishing amount of instruments in the cockpit. All the displays are designed to make the supersonic run as safe as possible and will alert the driver in the event of any malfunctions in the various gauges and tanks on the Bloodhound. Behind the wheel will be former Royal Air Force fighter pilot Andy Green, who holds the current land-speed record at 1,228 kilometres (763 miles) per hour.

The history of land speed

Thrust SSC

The first to break the sound barrier in its 1997 record-breaking run, it has set the current bar, on the Bloodhound must cross.

Bluebird Proteus CN7

The last of the famous father-son Bluebird brand, the British built CN7 cost £1 million and ran on a 3,057kW (4,100hp) engine.

La Jamais Contente

The first car purposely built to break records; this French vehicle reached its target in 1899 and was one of the last electrically powered cars before internal combustion engines took over.

Own a personal drone

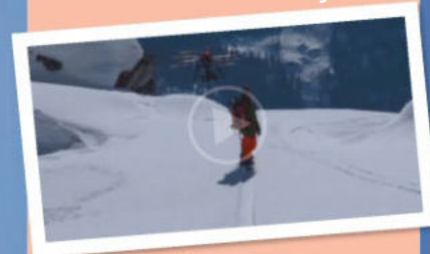
Meet the smart drone that's built for action

The Hexo+ is a device that could revolutionise the world of film and photography. Promising 'aerial filming for everyone', this superb piece of new technology will make close-up filming of unbelievable images possible. Crazier angles of unfolding action than ever before could become the future norm. Better still, perilous places to film such as sheer mountain faces and raging rivers will be accessible with the Hexo+. With no remote control, the small, lightweight drone will automatically follow its target and take an array of quality snaps. Still in the development stage, the futuristic device can fly at up to 70 kilometres (43.5 miles) per hour using its six propellers.

AMAZING VIDEO!

Drone on camera

www.howitworksdaily.com



SCAN THE QR CODE FOR A QUICK LINK

The drone in action

The Hexo+ follows its target while filming

Autonomy
No camera operator is necessary, allowing the drone to go where no cameraman would dare!

Funding
The Hexo+ project was only founded this year and still require more funding to get it (ahem) off the ground.

App-ready
The drone can be controlled by an app on your smartphone which can also provide live online video feeds.

Launch plan
The 'copter is due to be released next year and will reportedly lighten your wallet to the tune of £290 ($499).

For the brave
The product is ideally suited for extreme stunt enthusiasts who want to showcase their skills to the world.

Intuition
The technology used to follow you is called 'trajectory anticipation algorithm' which accurately predicts your next move.

Glow-in-the-dark plankton

An amazing sighting of luminous sea creatures off the Welsh coast

Best known as a food of choice for fish and whales, plankton have a few tricks of their own too. Chemical reactions known as bioluminescence occur in their body, which gives them the ability to glow blue, green, red or orange. The reaction produces energy, which makes particles vibrate and oxidise to create light. The lamination is used to warn off predators with the flash confusing, scaring and putting off anything that tries to eat the critters. Probably doesn't work that well on the hungry whales, mind you.

Luminous plankton sounds like science fiction, but is completely real

Pepper has been called "the world's first personal robot that can read emotions"

Do the robot

This advanced AI can dance and even understand human emotions

Artificial intelligence is currently booming in the tech world. French company Aldebaran Robotics, have created 'Pepper', a robot that can read human feelings, tell jokes, dance, sing and even help console people who have fallen on hard times.

The creators firmly believe this 'social robot' could live with a family and help them in their everyday lives. The friendly humanoid robot works by using senses to detect human emotion. It will then interact with the person according to the emotion.

'Pepper' doesn't have legs, instead using wheels, which utilise an ultrasound system to move through surroundings. Unconfirmed rumours are circulating whether a sister robot named 'Salt' is in development…

10 COOL THINGS WE LEARNED THIS MONTH

People who say like are, like, really thoughtful

Using the words 'um', 'like' and 'you know' may actually be a sign of thoughtfulness. That's according to a study at the University of Texas at Austin, which analysed recordings of more than 200 men and women. After totting up the number of times these words were used and comparing them to the volunteers' personalities, they believed there was a correlation between these words and conscientiousness.

A smart cup that knows what you're drinking

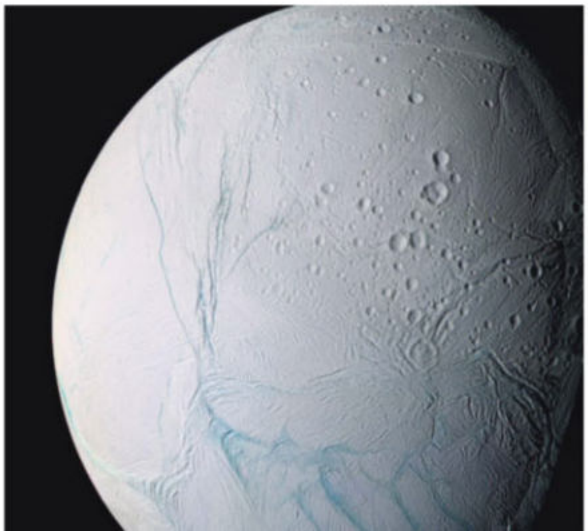
The latest health-related gadget set to revolutionise the way we keep track of what we consume. It's an intelligent cup called Vessyl that uses computing technology to detect exactly what's being poured inside. It calculates the calories, as well as showing you how hydrated you are and alerting you when it is time to drink again. The device is available to pre-order now for £59 ($99) from Vessyl's website (www.myvessyl.com).

Wrens teach eggs a secret password

Cuckoos lay their eggs in the nests of their feathered friends, leaving them to do all the hard work of raising them. To fight back, the fairy wren teaches their embryos a password while they're still in their eggs. When researchers played the sound of the Horsfield's bronze-cuckoo near the nest, they found fairy wrens increased their efforts to teach their password. What a cheep trick.

Possible underground ocean on Pluto's moon

Pluto orbits the Sun more than 39 times farther away than Earth and its surface is so cold it reaches -223 degrees Celsius (-369 degrees Fahrenheit) – far too cold for liquid water. But a new NASA-funded study found evidence that hints at a once-warm subterranean ocean on one of the planet's moons, Charon. Other moons have cracked surfaces with evidence of ocean interiors, including Jupiter's moon Europa. It could help in the hunt for alien life, as water is a key element.



Morbid fascination is very real

If you've ever found yourself watching a horror movie from behind the sofa and wondered why, there is an answer. A study by students from the University of Central Florida and Indiana University discovered that people exposed to blood and guts showed higher levels of attention despite having negative reactions to the content. They also found that we remember the content with disgust better, suggesting participants couldn't turn away.

Bionic pancreas to help diabetics

A biomedical engineer has developed a bionic pancreas to help his diabetic son. The machine can regulate blood sugar that a type-1 diabetic's organ cannot, liberating diabetic sufferers from checking their insulin levels, or self-administering the hormone. It's a small monitor that attaches to the body and sends results wirelessly to an iPhone app, which then calculates the amount of insulin needed. Work is ongoing to create an implantable device that will replace the real thing.

The car of tomorrow

It looks like a smartphone-car hybrid and that's essentially the goal for Toyota's exciting concept vehicle. It features a massive LED-screen exterior that allows for a fully personalised display, and the ability to change the paint job by uploading a unique digital skin or image. Designed to enable drivers to show off their personality, the Toyota Fun Vii also enables people to connect with their friends and family with smartphone-like displays when they're stuck in a traffic jam. They have to be careful when forming a full *Tetris* line, though…

Rats regret their mistakes

It seems humans aren't the only ones to regret making bad choices. Researchers at the University of Minnesota trained rats to do a task called 'restaurant row.' There were four food stops and a sound would indicate how long the rodent would have to wait for a treat. If they passed a 'good deal' to discover a 'bad deal' at the next place, they stopped and looked back. A study of the brain activity backed up the theory, proving rats have the ability to reflect on their choices.

Spurting plasma

This stunning image shows a stream of plasma bursting out of the Sun in May 2014. NASA says the eruption was minor and these kinds of events happen almost every day on the Sun, driven by powerful magnetic forces near the surface.

'The Beast' asteroid caught on camera

NASA used Earth-based radar to capture detailed views of a huge asteroid, nicknamed 'the Beast.' It's about 366 metres (1,200 feet) long and about half as wide. Radar is hugely useful for studying comets as well as asteroids, revealing details of their size and orbits.

An image collage of photos taken of the 'Beast' asteroid

Ocean hunters

These amazing feats of engineering bring the ocean depths closer than ever before

What lies beneath? This question has fascinated mankind for decades. We know more about the surface of the Moon than we do about our planet's deep oceans, as the limitations of planning a visit to the bottom of the sea are as many as venturing into space. But when nature throws problems at us, we hit back with technological solutions.

It's thought an English innkeeper, musing over the properties of buoyancy and water displacement, dreamt up the first submarine in 1580. From there, the principal of taking humans from sea level down to the deepest-known parts of the ocean in a pressurised cabin has grown into a colossal industry, important to scientists, the military and explorers alike.

But what are the benefits of diving so deep and what is there to see? Studying the seabed and its geological and topographical properties at certain regions can help us learn more about the surface of our planet. Scientists studying plate tectonics can learn plenty from ocean trenches, gaining knowledge that may lead to advancements in earthquake predictions and tsunami warning systems.

Similarly, the study of the decaying matter that collects on the ocean floor may help us to understand more about how carbon cycles through our ecosystems and how it is stored in the oceans. In turn this may have implications for our understanding of climate change.

Submersibles are manned submarines, usually carrying around three crew members. One of the most famous and longest-serving submersibles out there is Alvin, the first of its kind capable of carrying passengers, owned by the Woods Hole Oceanographic Institution in Massachusetts, USA. Also available for deep-ocean exploration and study are ROVs, or Remotely Operated Vehicles. These are robots that can be controlled from their parent ship, equipped with cameras and tools to take images and samples from the deep.

At the bottom of the ocean, hydrostatic pressure is a major adversary. For every ten metres (33 feet) in depth, the pressure ▶

Emerging technology is behind many of Virgin Oceanic's new deep-sea exploration vessel

Virgin Oceanic submersible

Explore Richard Branson's innovative craft for deep-ocean adventure, designed by sub builder Graham Hawkes

5 TOP FACTS SUB DISCOVERIES

RMS Titanic

1 Nautile, owned by French institute IFREMER, was one of the key explorers of the RMS Titanic from 1987. It helped map the area and collect artefacts from the wreck.

Hydrothermal vents

2 Researchers using Alvin in 1977 discovered the first hydrothermal vents in the Pacific Ocean. Alvin has since located over 24 vent sites in the Atlantic and Pacific.

Sea-floor spreading

3 Alvin, alongside French research subs Cyana and Archimade helped scientists confirm the theory of sea-floor spreading along the mid-Atlantic Ridge.

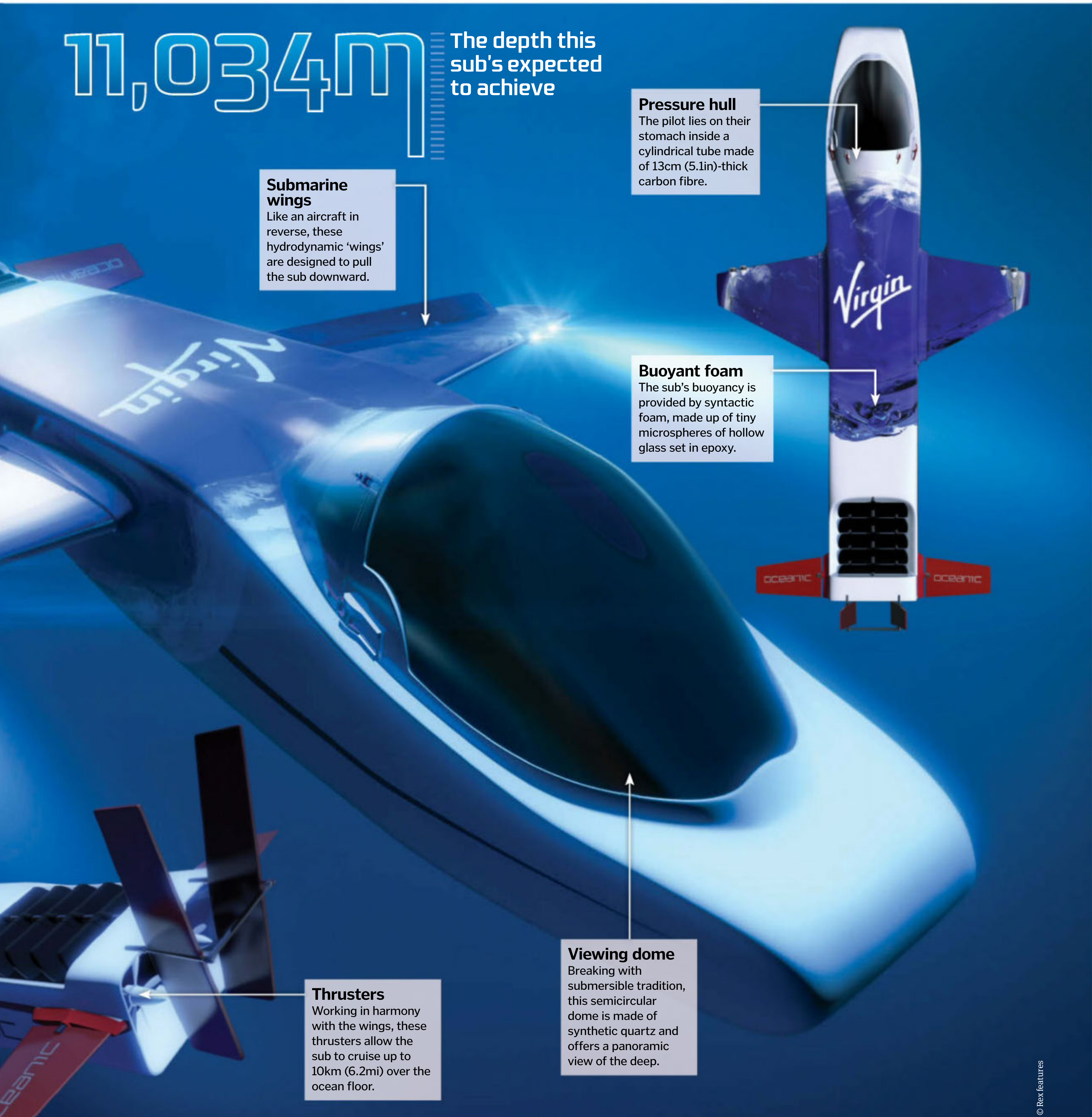
Under the North Pole

4 In 2007, Russian subs Mir I and Mir II sparked controversy when they placed a Russian flag on the seabed 4,200m (13,780ft) below the geographic North Pole.

Undersea volcanism

5 In 2009, researchers using the ROV Jason II made history when they recorded the first video and images of a deep-sea volcano erupting molten lava on the sea floor.

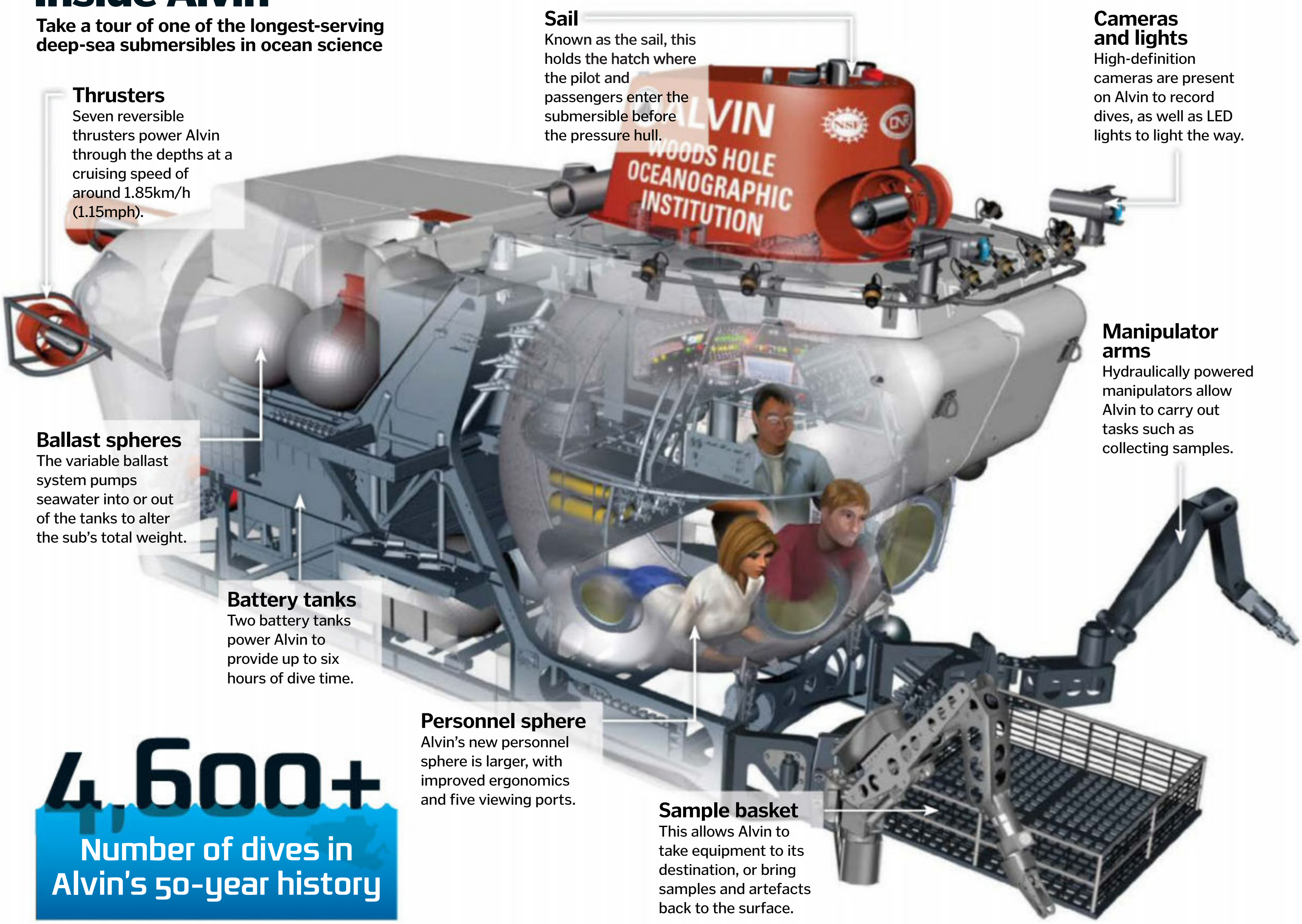
DID YOU KNOW? *A submarine can power itself onward, but a submersible usually needs support from a ship on the surface*



"To make submersibles and ROVs float, many possess ceramic spheres filled with air, packed into their body"

Inside Alvin

Take a tour of one of the longest-serving deep-sea submersibles in ocean science



4,600+

Number of dives in Alvin's 50-year history

increases by one bar (14.5 pounds per square inch). At full-ocean-depth, that means the pressure equals the weight of an elephant balancing on a postage stamp. To survive that, deep-sea craft need to be extremely tough.

The outer shells of subs and ROVs need to be made of a substance that won't buckle under the astonishing pressure. Titanium is often used, because it's incredibly strong, corrosion resistant and is also able to withstand both the freezing depths of marine trenches and the soaring temperatures of hydrothermal activity.

The pressure hull of a submersible is the area that needs to be hardiest of all, keeping the internal pressure comfortable for human occupation. A sphere is the most common form, as with this specific shape the pressure is applied equally. Many submersibles feature spherical personnel pods constructed of one element, with no joins that may weaken the structure. DOER Marine's Deepsearch submersible employs this technique, with their sphere made out of incredibly tough glass.

One submersible that uses a radically different pressure hull is Virgin Oceanic's sub. This features a cylindrical compartment made of 13-centimetre (5.1-inch) thick carbon fibre, capped with a viewing dome constructed of incredibly strong synthetic quartz.

Another key element of submersible design is buoyancy. The craft needs to descend, ascend and be able to 'hover' in the water column at the pilot's direction. Many submersibles, both manned and remotely-operated, use water bladders to provide ballast. These can be filled or dumped at will to ensure that the craft can manoeuvre within the water column.

To make submersibles and ROVs float, many possess ceramic spheres filled with air, packed in to their body. The spheres are often fitted alongside syntactic foam, a light substance made of glass microspheres mixed in epoxy resin. These features work alongside the ballast and also function as a safety feature. If the submersible encounters problems at depth, any expendable weight can be dropped and the buoyancy will lift the sub to the surface.

Remotely Operated Vehicles (ROVs) come in many different configurations, with a large range of depth capabilities and uses. Many are used by the oil industry for drilling support or

THE STATS
ALVIN'S SPECS

WEIGHT (kg) **20,412** | DEPTH **4.5km** | LENGTH **7.1m** | LIFE SUPPORT **72hrs** | NUMBER OF PASSENGERS **THREE** | MAX SPEED **2 knots**

DID YOU KNOW? *Alvin was temporarily lost at sea in 1968. It broke away from tethers and sank 1,524m [5,000ft] underwater*

Ask an oceanographer

Liz Taylor, president of DOER Marine reveals the challenges of deep-sea exploration

What are the main issues faced by deep-sea exploration today?
We have the capacity and technology to build both manned and unmanned systems that can reliably reach the deepest parts of the ocean. What is lacking is the willingness to effectively fund exploration; for meaningful exploration to occur, we must be willing to accept that not all expeditions will go as predicted. Sometimes, the greatest discoveries are made by accident.

What technology has DOER Marine developed?
We have worked to develop applied science, multi-mission ROVs and submersibles for a broad array of tasks. Our systems are designed to evolve with new technology and client needs. For example, the 6000m [19,685ft] ROV delivered to the University of Hawaii last year supports a variety of disciplines, from backing up the manned submersibles program, to servicing the Station Aloha Ocean Observing System, documenting historic wrecks and old munitions sites as well as carrying out basic geological and biological survey and sampling tasks. It is equipped with HD cameras, supports multiple sensors and has Gigabit Ethernet maximising the data collecting capacity.

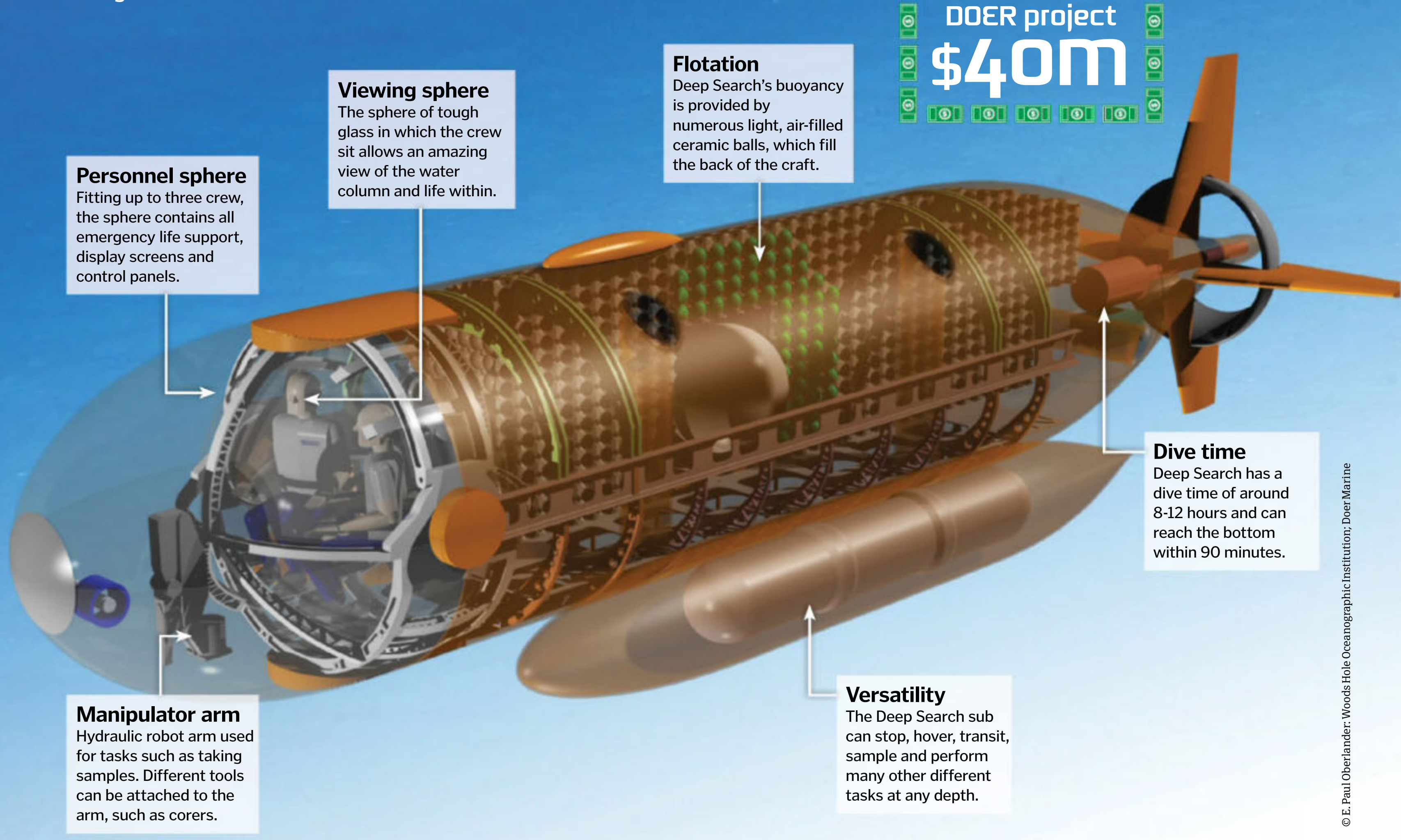
What are the main advancements in the field in the last few years?
The major advances have been in materials science, processing power and reduced size of many components. However, for the human-occupied submersibles, battery technology advances have been a game changer.

What are the major discoveries that new deep-sea technology has helped to unearth?
Some of the most interesting discoveries that have been made have to do with promising new medicines from the sea. Scripps Institute of Oceanography scientists have been working with microbes found to be effective in combating flesh-eating bacteria. The Canadian Cancer Society has funded research involving deep-water sponges. Sponges are also being studied and modelled in artificial kidney research. The biggest discovery, really, is how much more there is still to know about the ocean.

What does the future hold for deep-sea exploration?
There has been much talk about moving toward the exclusive use of robots and sensors [in deep-sea exploration]. However, sensors and drones are great tools to have but they don't possess intuition and they can't act on a hunch. They can't be surprised nor can they return to directly share stories, igniting the imagination and compelling others to care. Knowing what we do now know about the ocean, and its importance to our survival, I think we will continue to "go down to the sea in ships" (and in submersibles) but perhaps more as stewards rather than as despoilers.

DOER Marine's Deep Search

The torpedo-shaped sub that allows direct human observation throughout the water column



"The pilot and passengers need to be kept at a constant pressure [...] and supplied with breathable air"

sub-sea construction, the navy for search and recovery missions and by scientists to explore the ocean and collect data.

All ROVs have a camera that links a video feed to their parent boat. From here, the operator is able to guide the vehicle through a task. The robot will often have specialised functions, for example hydraulically powered manipulator arms that are fully wieldable by the person at the robot's controls. ROVs can be used to accomplish tasks that humans simply couldn't do, and can be used in the ocean in the same way scientists use rovers and landers in space.

Some ROVs operate using a fibre-optic umbilical tether. This connects the robot to the boat and passes information between the control centre and the undersea unit. Using a tether can limit the ROV's depth capabilities, but it also provides a level of security in that the ROV is less easily lost at sea. That is, until the tether becomes tangled or snagged. Other ROV systems are able to operate tether-free, either breaking away from their cable at depth, for example Woods Hole Oceanographic Institution's (WHOI) 'ABE', which stands for Autonomous Benthic Explorer.

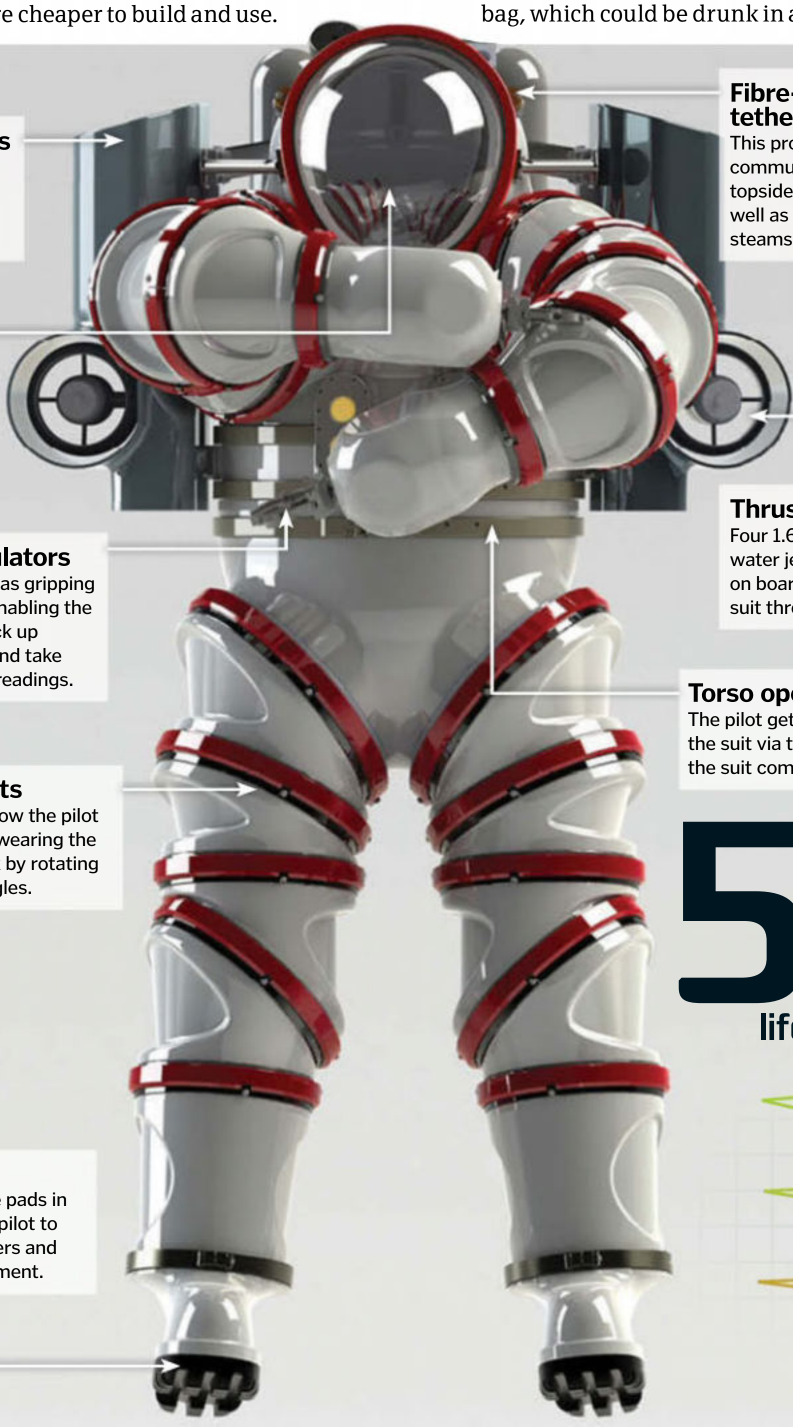
The advantage of using a Remotely Operated Vehicle (ROV) to explore the deep ocean, recover shipwrecks or collect samples is that it poses no risk to human life. Removing the human element from the equation also means ROVs are cheaper to build and use.

However, many oceanographers argue that the work of a robot underwater is no comparison to the reactions of a human brain. Life support in submersibles is a huge part of their makeup. The pilot and passengers need to be kept at a constant pressure, comfortable temperature and supplied with breathable air. The CO_2 and water vapour exhaled by the crew needs to be removed (this is often achieved using the same method as used on a space ship) and contingency scenarios need to be in place for every conceivable emergency. In James Cameron's Deep Sea Challenger expedition, his pilot sphere was engineered to condense water vapour and sweat from the pilot into a special bag, which could be drunk in an emergency.

Personal deep sea exploration

As mere humans, superpowers are beyond our reach but sometimes technology lets us mimic these powers pretty well. If you've ever dreamt of breathing underwater or exploring the ocean depths without a submersible, then take a look at the Iron Man-esque ExoSuit. With regular SCUBA gear, divers are limited by the effects that pressure has on the human body and by lengthy decompression stops. However this 'wearable' submersible is a suit that can take the pilot from sea level all the way down to a dizzying 305m (1,000ft) in relative comfort, with up to 50 hours of life support. Made of aluminium alloy and weighing in at 250kg (550lb), the astronaut-style suit also has four thrusters to propel it. The suit, working alongside an ROV equipped with cameras and video equipment, will enable marine scientists to get first-hand experience of the life they study beneath the waves.

A prototype of the innovative ExoSuit in preliminary testing



Oxygen systems
With up to 50 hours available, the suit's O_2 stores allow for multiple dives.

Viewing port
The port is teardrop-shaped, allowing a wide field of view down the chest level for the pilot.

Manipulators
These act as gripping devices, enabling the pilot to pick up samples and take scientific readings.

Rotary joints
These joints allow the pilot to move while wearing the suit. They work by rotating at different angles.

Foot pads
Pressure-sensitive pads in the feet allow the pilot to control the thrusters and direction of movement.

Fibre-optic tether
This provides two-way communications with topside scientists as well as live video steams from the suit.

Thrusters
Four 1.6-horsepower water jet thrusters are on board to propel the suit through the water.

Torso opening
The pilot gets in and out of the suit via the torso, where the suit comes apart.

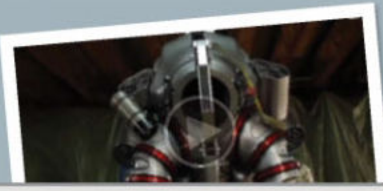
50 hours of life support

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

Check out the deep-diving Exosuit in action

www.howitworksdaily.com



DID YOU KNOW? Russian submersibles MIR I and MIR II can take tourists to the depths for a hefty price of £205,200 ($350,000)

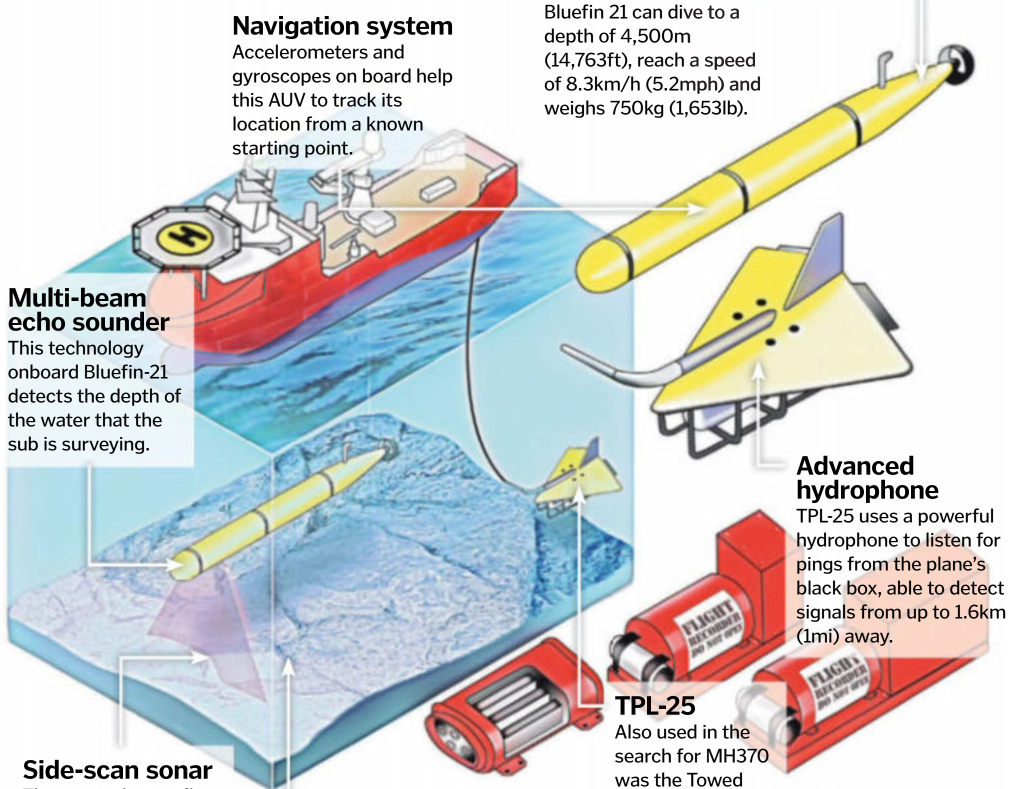
Search and rescue subs

One of the great uses for submersibles and remotely operated vehicles is their ability to go where humans can't, and for long periods of time. This is why they are incredibly useful as search and rescue devices. In the past, the 1966 Woods Hole Oceanographic Institution's DSV (Deep Submergence Vehicle) Alvin was tasked with locating a missing hydrogen bomb, lost in a plane crash in the Mediterranean Sea. Alvin searched for two months before recovering the bomb, complete with attached parachute, under 762m (2,500ft) of water.

A more recent example of submersible search and rescue is the use of autonomous underwater vehicle (AUV) Bluefin-21 in the search for missing plane MH370. On 8 March 2014 a Malaysia Airlines flight from Kuala Lumpur to Beijing disappeared from radar and was presumed to have crashed into the southern Indian Ocean. With such a huge search area to cover in order to find the missing plane, Bluefin-21 was drafted in to help the effort.

The AUV is equipped with side-scan sonar – acoustic technology that creates pictures of the seabed using reflected sound waves instead of light. Bluefin-21 can be programmed to search a particular area, sweeping and scanning 50m (164ft) above the seabed for 24 hours, after which the data can be downloaded and analysed. This creates a 3D map of the area and highlights any wreckage that could potentially be linked to the missing plane.

Unfortunately, despite having scanned over 850km^2 (328mi^2) of the vast search area, at the time of writing Bluefin-21 has yet to locate the missing aircraft.



Navigation system
Accelerometers and gyroscopes on board help this AUV to track its location from a known starting point.

Vital stats
Bluefin 21 can dive to a depth of 4,500m (14,763ft), reach a speed of 8.3km/h (5.2mph) and weighs 750kg (1,653lb).

Multi-beam echo sounder
This technology onboard Bluefin-21 detects the depth of the water that the sub is surveying.

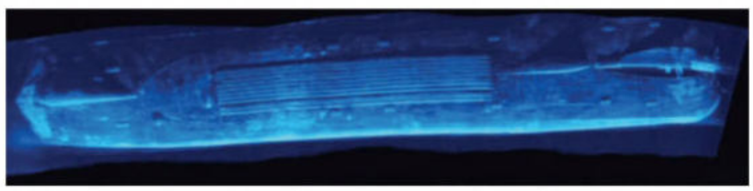
Advanced hydrophone
TPL-25 uses a powerful hydrophone to listen for pings from the plane's black box, able to detect signals from up to 1.6km (1mi) away.

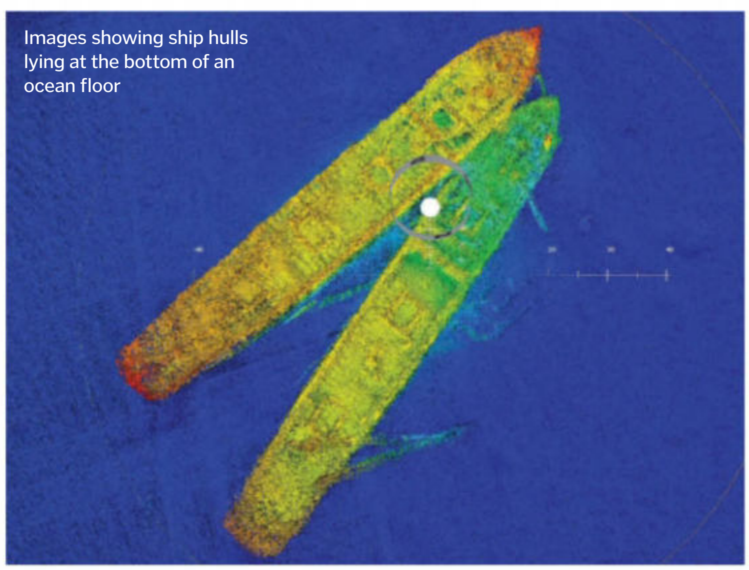
TPL-25
Also used in the search for MH370 was the Towed Pinger Locator 25, towed behind a research vessel.

Side-scan sonar
This maps the sea floor to show if any fuselage has come to rest on the ocean floor.

Distance searched
The TPL-25 system can search an area of over 260km^2 (100mi^2) per day.

The design of Bluefin-21 is reminiscent of a torpedo





Images showing ship hulls lying at the bottom of an ocean floor

"The robot can be programmed to venture off alone and scan the sea floor using sonar mapping"

Other types of undersea robots are capable of guiding themselves, after being programmed, to carry out a task. These are known as AUVs, or autonomous underwater vehicles. This kind of mini submarine is used for scanning larger areas of the ocean, as AUVs are able to work for much longer than a manned sub and dive much deeper than an ROV.

One such device is Nereus, owned by WHOI. This is a HROV, (H for Hybrid). The robot can be programmed to venture off alone and scan the sea floor using sonar mapping and camera systems; if it finds anything interesting it can then be returned to the site via a lightweight tether and equipped with extra sampling apparatus at the command of scientists aboard the ship.

A similar method is used for other, smaller AUVs such as Bluefin-21, developed by Bluefin Robotics. This AUV is capable of mapping the sea floor using echo sounders and side-scan sonar for up to 24 hours. GPS systems then return it to a parent ship, where the data is then analysed by the scientists.

If anything of interest is found, Bluefin-21 can return to the exact site with high-resolution imaging gear on board to give scientists a closer look. Alongside the external features, submersibles and ROVs require a whole host of other technology on board.

The deepest realms of the ocean are pitch black, so most submersibles and ROVs have powerful lights to provide illumination in the depths. These, as well as everything else on the sub, are battery powered. The battery life of a sub governs exactly how much 'bottom time' is allowed, alongside the ascent and descent rates. Many submersibles still use lead-acid batteries in their power cells, but lithium-ion is now being introduced into many. Stage II of Alvin's latest upgrade is set to see the inclusion of lithium-ion batteries to extensively improve the sub's bottom time.

Typical manned submersibles will have an on-board computer to log data and monitor all electronic systems. As well as GPS and navigational tracking systems, sonar, communications apparatus (Cameron's record-breaking sub could even send text messages), subs and ROVs will also have many different sensors to monitor the parameters outside the craft and send the data back for analysis in real time. Many submersibles and ROVs can also be fitted with all kinds of specialised equipment, depending on the task that it is set to accomplish.

History of deep-sea explorers

Take the plunge into a story of the ever-increasing depths humans have reached

1 Deepsea Challenger
10,908m (35,787ft)

2 Exosuit
305m (1,000ft)

3 Virgin Oceanic
11,034m (36,201ft) (expected)

4 SonSub Innovator
3,000m (9,843ft)

6 Alvin
4,500m (14,764ft)

7 Bluefin-21
4,500m (14,764ft)

8 Shinkai 6500
6,500m (21,325ft)

9 Kaiko 7000II
7,000m (22,966ft)

11 Johnson Sea Link
914m (3,000ft)

12 Seaeye Lynx ROV
1,500m (4,921ft)

13 Deep Worker 3000
1,000m (3,280ft)

14 Magnum Plus
3,962m (13,000ft)

15 Hercules
4,000m (13,123ft)

16 Sentry
6,000m (19,685ft)

17 MIR DSV
6,000m (19,685ft)

18 Nautile
10,902m (35,768ft)

10,908m

DEEPEST-EVER SUBMERSIBLE DIVE

In his Deep Sea Challenger submersible, filmmaker James Cameron achieved a record-breaking solo dive to the bottom of the Challenger Deep in the Mariana Trench, Western Pacific Ocean.

DID YOU KNOW? *The first-ever tethered ROV was named POODLE, developed in 1953 by French inventor Dimitri Rebikoff*

5 Deepsearch
5,000m (16,404ft)
(expected)

10 Deep Flight Super Falcon Mark II
120m (394ft)

FAR RIGHT It took engineers seven years to develop the sub

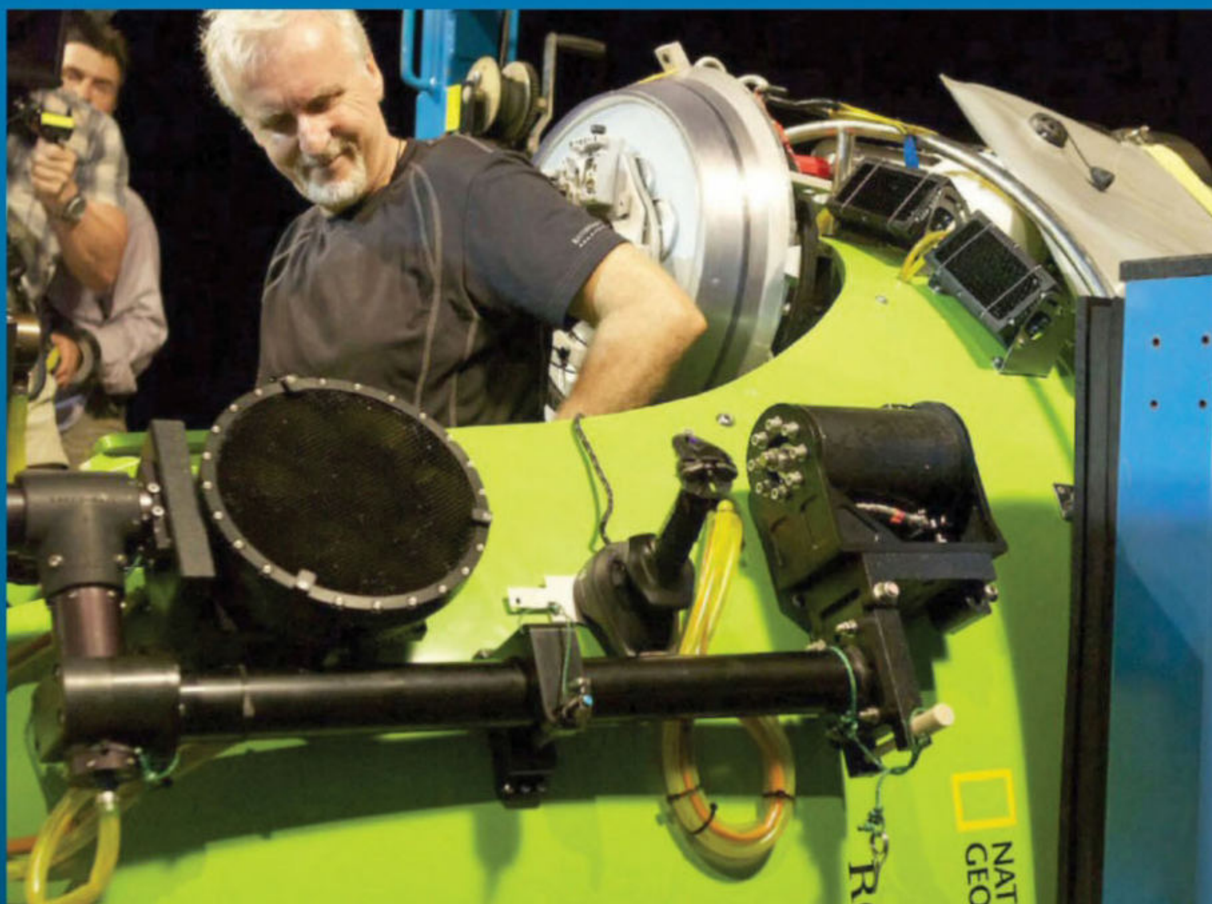
RIGHT James Cameron prepares to descend to the Mariana Trench

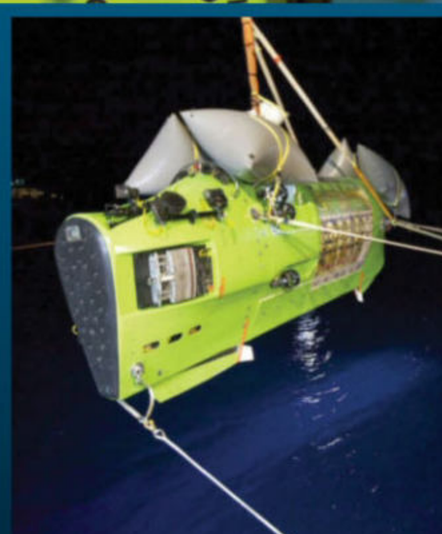
The Challenger Deep revisited

Fast-forward 54 years, and the abyssal Mariana Trench gets her second batch of human visitors. No one had returned since Piccard and Walsh's adventure, until James Cameron completed his Deep Sea Challenger expedition on 26 March 2012.

Deep Sea Challenger is a submersible like no other. Nicknamed a 'giant runner bean', the sub's architecture veers away from the bulky cuboids of standard sub design and is long, thin and descends vertically into the depths. The sub gradually spins on its ascent and descent to keep it on track. The pilot sits inside a tight, spherical cockpit with custom circuit boards powered by large versions of model aeroplane batteries. The exterior has a huge bank of lights to illuminate the voyage.

Cameron descended to 10,908m (35,787ft) armed with high-definition cameras and video equipment alongside state of the art sampling apparatus. Piccard and Walsh were unable to document their dive, but Cameron has more than made up for that, with his feature-length documentary about Deep Sea Challenger set to hit cinemas in the near future.





"This incredible machine is set to launch a non-stop, round-the-world trip powered only by the Sun"

Solar-powered aircraft

The flying machines that are fuelled only by the Sun

As the search for renewable and carbon-neutral forms of energy intensifies, solar energy is leading the way in fuelling the next generation of aircraft.

One aircraft breaking boundaries in this area is the Solar Impulse 2. This incredible machine is set to launch a non-stop, round-the-world trip powered only by the Sun. It will do this by using 72-metre (236-foot) wide wings, each of which will be carrying over 8,500 solar cells, powering four electric motors and four lithium batteries. Despite this astonishing wingspan, the entire aircraft will only weigh 2,300 kilograms (5,071 pounds), about as heavy as a large great white shark.

Another major player in the world of solar powered aviation is Solar Flight. Their newest project is Sunseeker Duo, which is the only two-seater solar-powered aeroplane in operation. It follows a similar pattern to the Solar Impulse 2, with long wings covered with solar panels and a lightweight body. Its panels have been improved to become 50 per cent more efficient than their predecessors. It can fly for 12 hours and its engine produces 25 kilowatts (33.5 horsepower) of power.

The main question with using solar power is 'what happens at night?' During the day, not all the energy is used. Enough will be stored in the batteries to allow the aircraft fly at night.

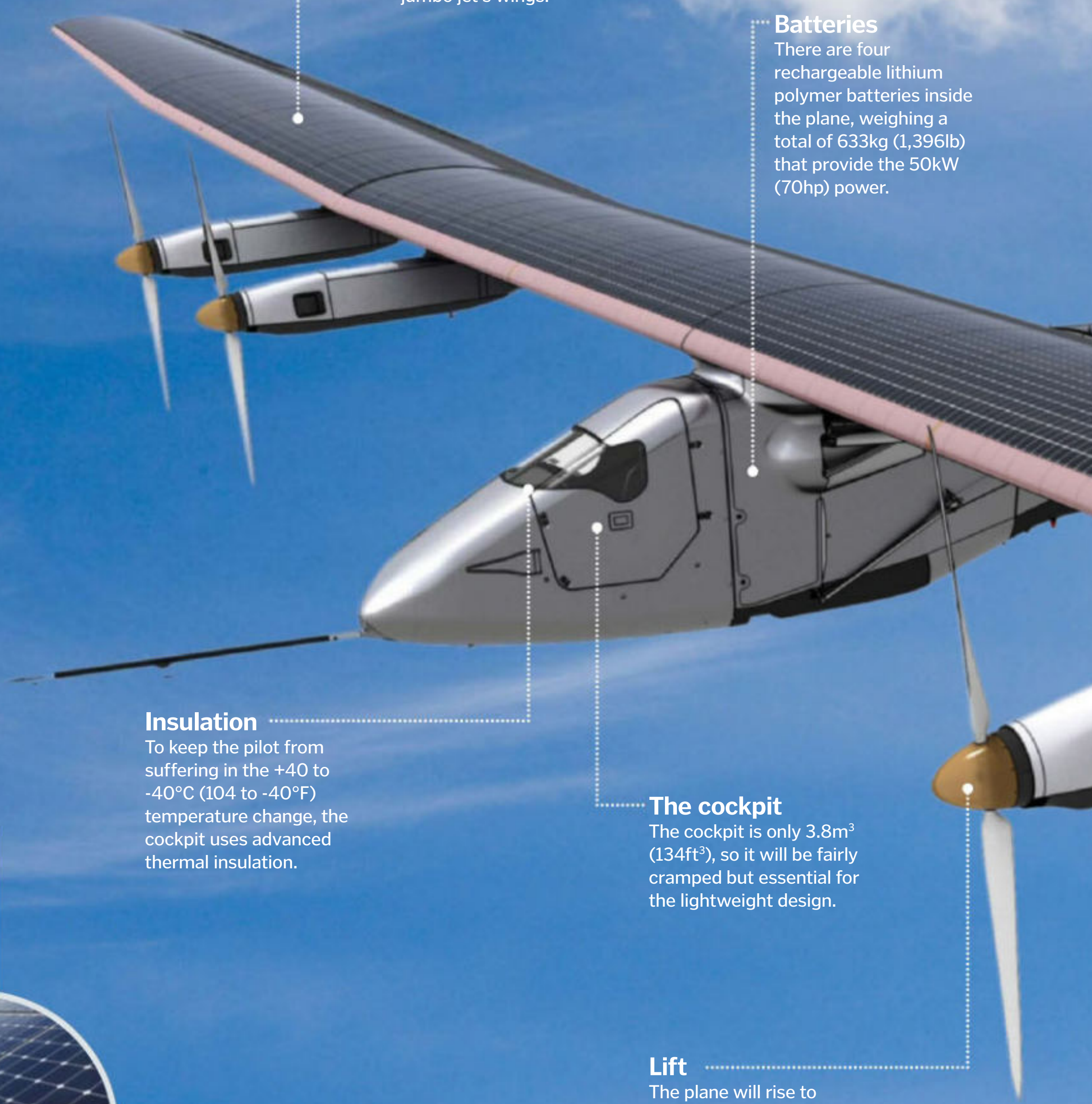
The next challenge for solar-powered aviation is to be able to carry multiple passengers, so hopefully one day soon holidaymakers will be able to use the Sun on their way to soaking it up.

How solar panels work

We have heard a lot about solar panels converting sunlight to energy, but how does that process actually work? Inside a solar panel is a number of silicon cells, placed on top of each other. One of the silicon atoms has all its electrons, while the one beneath it has a few missing. In order to restore the balance, the full silicon atom transfers electrons to the one below, but it needs light to trigger the process. Once the sunlight hits the panel, electrons are transferred from one silicon cell to the other, thus creating an electric current that powers a load.

Anatomy of a solar aircraft

How the Solar Impulse 2 gets off the ground and stays there

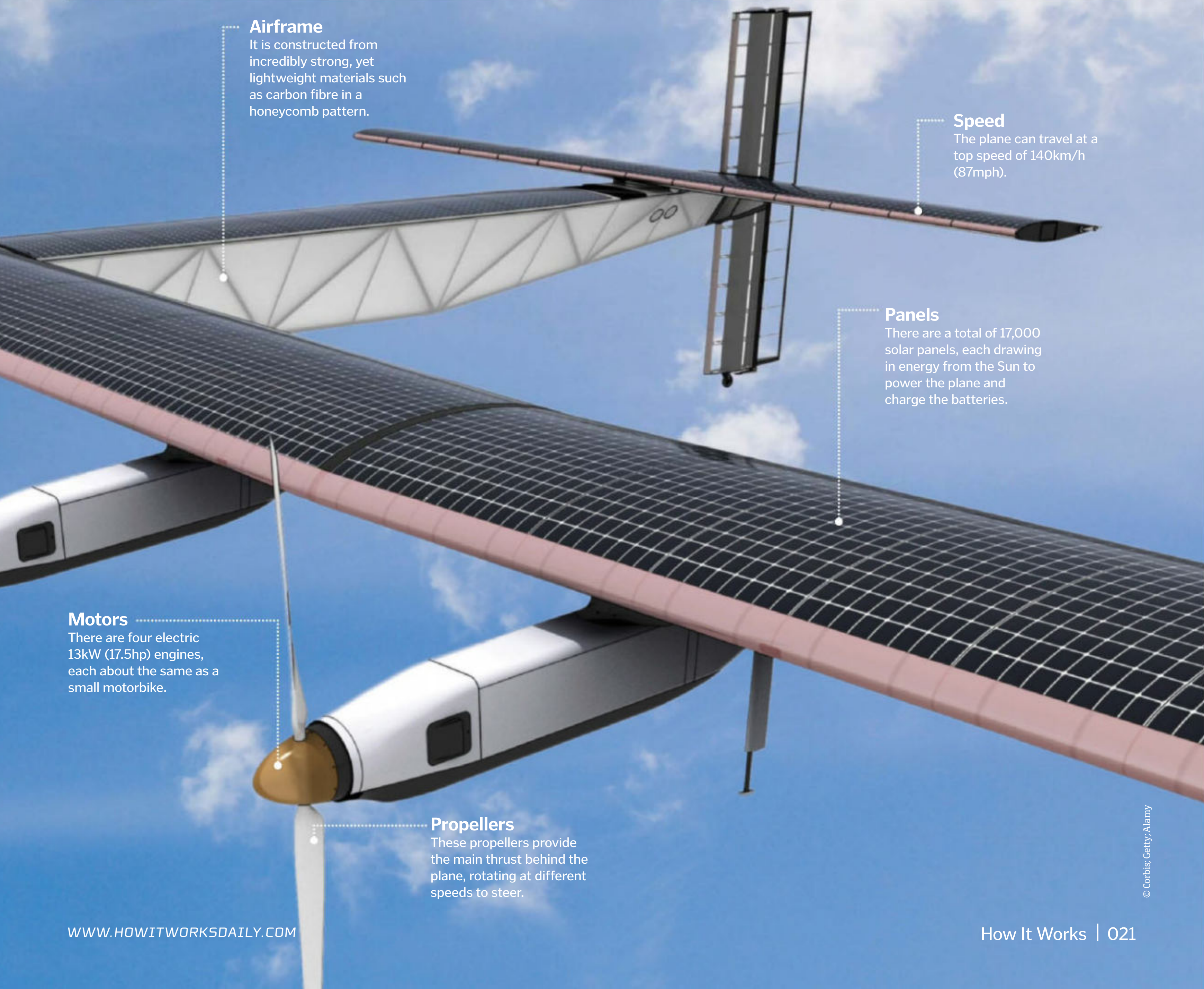


DID YOU KNOW? *In 2013, the original Solar Impulse prototype flew across the USA without a single drop of fuel*

Despite the massive wingspan, the Solar Impulse weighs about the same as two small cars

Close up power

ESA's Solar Orbiter will be getting a ridiculous boost of solar energy when it takes off in 2017 as its mission is to get closer to the Sun than any probe has before, in order to take incredible pictures of the star. With its 3.1-metre x 2.4-metre (10.2-foot x 7.9-foot) sunshield, this craft will travel just 42 million kilometres (26 million miles) away from the Sun to take high-resolution images and perform experiments. It has been rigorously tested, as it will experience temperatures ranging from 520 degrees Celsius (968 degrees Fahrenheit) to -170 degrees Celsius (-274 degrees Fahrenheit). Its aim is to help scientists lean more about the inner heliosphere and how solar activity affects it, answering questions about solar winds, coronal magnetic fields and solar eruptions.



"This new system can handle the latest in satellite-navigation technology and internet connections"

Antennas of the future

Revolutionising the humble aerial for a new age

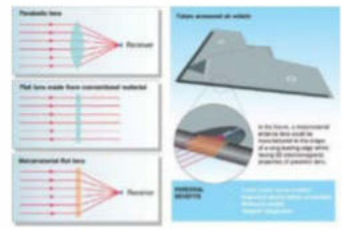
Wi-Fi, Bluetooth and 3G can send the lowly bog-standard car antenna into a spin. In order to handle today's abundance of portable and wireless technology, a new type of antenna will soon be racing its way into our vehicles. It has been developed and issued by the European Commission's Intelligent Car Initiative.

This new system can handle not only modern radio frequencies like DAB but also the latest in satellite-navigation technology and internet connections. Millimetre wave-integrated antennas and other smart antennas will connect to infrastructure systems to alert the driver to upcoming hazards and traffic information among other things.

The antenna must have a large set of features. The bandwidth needs to be wide so it can access as many frequencies as possible and the polarisation must match the gadget it is trying to connect to. To ensure this is possible, a new 'antenna hub' has been devised to maximise connectivity. This hub will connect any relevant gadget, whether it be for navigation, music or internet.

Military antennas

A new type of antenna is being developed by BAE Systems to make aircraft even more aerodynamic. The new flat lens is far superior to the curved parabolic and conventional flat lenses, as now only a single antenna will be used to save weight and enhance the streamlined capabilities of the craft. The process is known as transformation optics and the best properties of a curved lens (electric conduction) are accommodated by the best features of a flat lens (aerodynamics). Large bandwidths will be accessible without compromising speed and handling.



An innovative new flat lens will have all the properties of a curved one

The Intelligent Antenna Module from German company Kathrein is an example of the new breed of antennas

The advanced Taranis could utilise new antenna tech

Rather than use energy-sapping street lighting, glowing lines will illuminate at night to highlight the road ahead

The paint will glow different colours to alert the driver to road temperatures so they can respond accordingly

Glow-in-the-dark roads

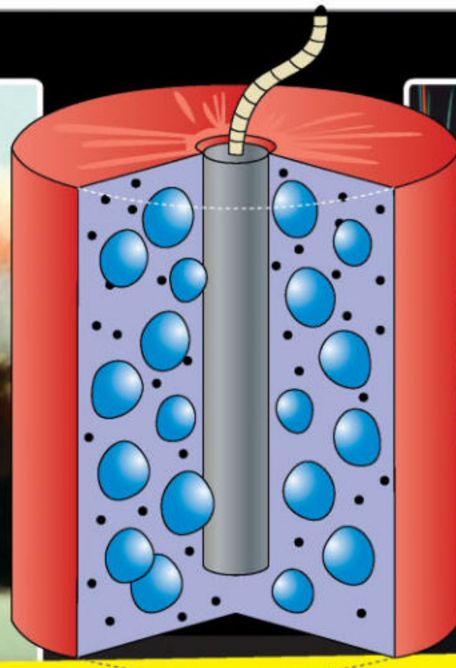
Streetlights to be switched off in favour of luminous paint?

The world's infrastructure is constantly being improved and updated to accommodate the ever-increasing amount of traffic on the roads. One of these developments is the use of glow-in-the-dark lining on the highway contours.

The brainchild of designer and innovator Daan Roosegaarde and Dutch company Heijmans, it is part of a development known as Smart Highway and will strive to improve road safety and travel efficiency. Using a photoluminescent powder, the invention would lessen the need for street lighting, which will save vast amounts on energy and material costs and also lessen light pollution. The powder is charged during the day by solar energy and will provide ten hours of light on one charge.

Another invention is dynamic paint. Instead of night lighting, the paint is based around temperature fluctuations. So when the climate plunges into sub-zero conditions or undergoes a heat wave, the paint will show drivers the potential hazards that lay ahead. These innovative designs are set to be released this year, while other parts of the Smart Highway family such as electric priority lanes and wind lights are intended to follow shortly after.


Why do materials ignite?




Rock blasting


Special effects

THE SCIENCE OF EXPLOSIONS

FIREWORKS • VOLCANOES • DEMOLITION • SPECIAL FX & MORE

Revealing the crazy chemistry at work behind really big bangs

We might not hear an almighty bang, but we experience explosions all the time. From the intentional ones, such as your car's internal combustion engine, to the kind we can't ignore, like violent blasts of ash and magma spewing from a volcano or a fireball the size of the Sun in a Hollywood blockbuster. This sudden release of energy, combined with scalding temperatures and expanding gas, occurs when an explosive has reacted with a detonator, which is often a spark or a flame.

Explosions blow things up because the sheer force and speed of the expansion pushes them out, like blowing up an inflatable ball until it pops. The only difference is that blowing up a ball happens a lot more slowly! The billowy flame that usually comes with an explosion is from that spark igniting and being carried outward by the expanding gas, while the deafening boom is caused by airwaves travelling at incredible speeds.

Explosive materials are categorised as 'high' or 'low' explosives, according to the speed at which they expand. Materials that detonate by an explosive shock wave are classed as high explosives because the chemical reaction moves faster than the speed of sound. Low explosives, on the other hand, are materials that deflagrate, or 'burn down.' This is when combustion moves through a gas or an explosive material at subsonic speeds. For this reason they're better at moving objects, like in an internal combustion engine or fireworks. Deflagration systems are often found in the kind of explosives we use for constructive reasons, such as demolition and mining. They rely on us being able to control explosions, and you can discover exactly how we do this over the next six pages.

300dB

LOUDEST EXPLOSION EVER

When a meteoroid slammed through the Earth's atmosphere and exploded mid-air over Russia in 1908, creating a blast estimated at 300 decibels. It released the same energy as 185 Hiroshima bombs.

DID YOU KNOW? *The word explode comes from the Latin theatrical term explodere, meaning "to drive out through clapping"*

"Around 200 BCE, the Chinese noticed that bamboo sticks in their bonfires exploded with a bang"

INCREDIBLE FIREWORKS

THE SPARK BEHIND YOUR NEW YEAR CELEBRATIONS EXPLAINED

Fireworks were first invented by the Chinese, pretty much by accident. Around 200 BCE, they noticed that bamboo sticks in their bonfires exploded with a bang. This happened because the fast-growing bamboo traps pockets of air inside its stalks, so when the oxygen comes into contact with the fire, a huge reaction takes place, resulting in light and sound.

The Chinese took this a step further and created the first form of gunpowder, mixing sulphur, saltpetre (potassium nitrate), arsenic disulphide and honey. When set on fire, this produced an explosion caused by the sulphur and honey acting as the energy source for the reaction and the potassium nitrate providing the oxygen. Honey was replaced with energy-dense charcoal and the mixture was put in tubes and angled at enemies who were terrified by the loud bangs and bright sparks. At this point, fireworks divided into weaponry and spectacular crowd-pleasing displays.

In the 1830s, scientists in Italy realised that by adding a metallic salt like strontium or barium and chlorine powder, the light that was created took on the colour of the salt. Slow-burning gunpowder was used as a fuse to fire the rocket into the air, while inside, potassium-rich gunpowder allowed for a bigger reaction, faster and hotter with a more impressive explosion.

Fireworks are a scientific marvel, taking an example of nature – the oxygen in a bamboo stick causing an explosive reaction – and turning it into a spectacle.

What makes the colours?

We go inside the vibrant explosion of a firework to see how it really works

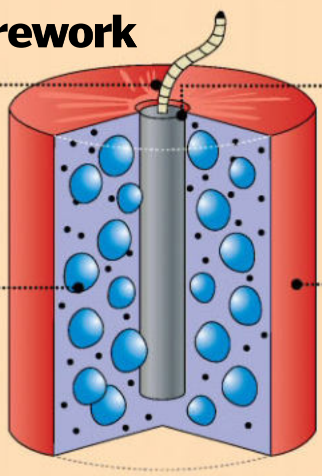
Copper (blue)
Despite being reddish-brown in colour, copper emits blue light when it burns.

Strontium (red)
Strontium is the reddish element that creates the warm red light of a firework.

Anatomy of a firework

Ignition
Once the spark reacts with the gunpowder in the middle of the firework it causes an intense reaction and the gunpowder explodes outward in a shower of light.

Coloured chemicals
This layer has coloured salts reacting with the gunpowder, producing the different coloured sparks. The very middle of the firework houses a small shell that produces the signature bang.



Liftoff
The firework is blown into the sky from a mortar – essentially a tube with more gunpowder at the bottom. Once lit, the combustion spreads to the next layer of material and ignites it.

Shell
A modern firework has a plastic shell, which will explode once the charge ignites the gunpowder in the middle of the firework. This burns slowly as the firework is blown into the air.

STRANGE BUT TRUE
TASTY EXPLOSION

Switzerland made a firework out of what?

A Chocolate **B** Cheese **C** Cuckoo clocks

Answer:
On New Year's Eve 2002, the people of Zurich, Switzerland were treated to a 3m (9.8ft) high firework made of chocolate. Inside the firework it also contained 60kg (132lb) of delicious Swiss Cailler chocolates.

DID YOU KNOW? *The biggest-ever fireworks display consisted of 479,651 fireworks and took place in Dubai on New Year's Eve 2013*

Sodium (yellow)
This soft metallic element creates a yellow light when reacting with gunpowder.

Barium (green)
This silvery-grey alkali metal oxidises rapidly, creating a green light.

Copper plus strontium (purple)
No single element can create a violet burst, but mixing copper and strontium will create a rich purple.

Calcium (orange)
Another alkali metal, calcium reacts with reasonable strength, therefore providing an orange light to displays.

Magnesium (white)
The intense, incredibly hot reaction with magnesium creates a white-hot light.

The scale of reactivity

Certain elements are more reactive than others because they have a spare electron. Atoms like to have a full shell of electrons as this is what makes them stable. If an atom has seven out of a possible eight electrons in its shell, for example, it will do all it can to gain that final electron. Likewise, an atom with a single electron in its outer shell will try hard to lose it. Fluorine is the most reactive element of all, with an unmatched ability to attract electrons.

Most reactive

- Fluorine
- Caesium
- Potassium
- Lithium
- Xenon
- Helium

Least reactive

What makes a bang?

You start off with an element, such as magnesium, that is made up of a large number of molecules that contain electrons, protons and neutrons. The spark of fire will heat up the electrons and excite them. As they get more excited, they are released from their molecular bonds. This results in both a physical movement of the electrons away from the nucleus and a release of the energy that has built up during the heating stage. The energy released can trigger further interactions, in turn creating a chain reaction. The higher the initial energy of the spark, the quicker the electrons get excited, resulting in a more violent explosion.

A burning magnesium ribbon

"As [the magma] grows, little pockets of gas begin to form and rise, much like in a bottle of fizzy drink"

EXPLOSIVE VOLCANOES

WHAT CAUSES THE MOST AWE-INSPIRING EXPLOSIONS IN NATURE?

Volcanoes are some of the most massively destructive things in nature, with the ability to spew tons of red-hot magma for miles, leading to chaos and destruction. The reason behind what causes this is down to pressure. The magma, which is less dense than the rocks around it, rises to the top of the volcano.

As it grows, little pockets of gas begin to form and rise, much like in a bottle of fizzy drink. This increases the pressure inside the volcano more and more, until eventually the pressure is unbearable and, just like when you take the lid off that fizzy drink, it explodes high into the sky. However, the material that explodes isn't sweetened carbonated liquid, but 1,300-degree-Celsius (2,372-degree-Fahrenheit) molten rock, hot gas and ash that has been known to go as high as 45 kilometres (28 miles). As soon as it explodes out of the volcano, the magma turns into lava, which flows down the side of the mountain, where it cools and solidifies into igneous rock.

Magma is nearly half oxygen and just over one-quarter silicon, with aluminium, iron, calcium, sodium, potassium and magnesium making up most of the rest of it. Eruptions take place when water is present in the magma and sulphur-dioxide and carbon-dioxide bubbles form. The pressure increases and the water becomes less able to dissolve in the magma, so separates. That means there's an even higher concentration of gas bubbles in the magma. The magic number for an eruption is 75 per cent gas content, which is enough to force the magma up and out.

Volcanic eruptions are among nature's most impressive spectacles

The explosive process

What happens when the pressure gets too hot to handle?

Highest, fastest, hottest, loudest

The tallest-ever volcano plume measured 45 kilometres (28 miles), which is the same as five Mount Everests.

Pyroclastic flows are incredibly fast waves of rock fragments and hot gases that can move away from the volcano at up to 480 kilometres (300 miles) per hour.

The hottest lava comes from volcanoes made up of basalt rock and can reach 1,250 degrees Celsius (2,282 degrees Fahrenheit). This is pretty impressive as Venus, the hottest planet in the solar system, only reaches 464 degrees Celsius (867 degrees Fahrenheit).

The eruption of Krakatoa in 1883 was recorded at 180 decibels from 160 kilometres (99 miles) away. This is about the same volume as a Space Shuttle launch up close.

A depiction of the eruption at Krakatoa in 1883

5 TOP FACTS VOLCANO FACTS

Under pressure
1 The force from an exploding volcano is about 42kg/cm2 (600psi), which is more than ten times the pressure in a fully inflated mountain-bike tyre.

Higher ground
2 Because the Earth is wider around the equator, Ecuador's Chimborazo volcano is the furthest point from the Earth's centre, even though Everest is taller.

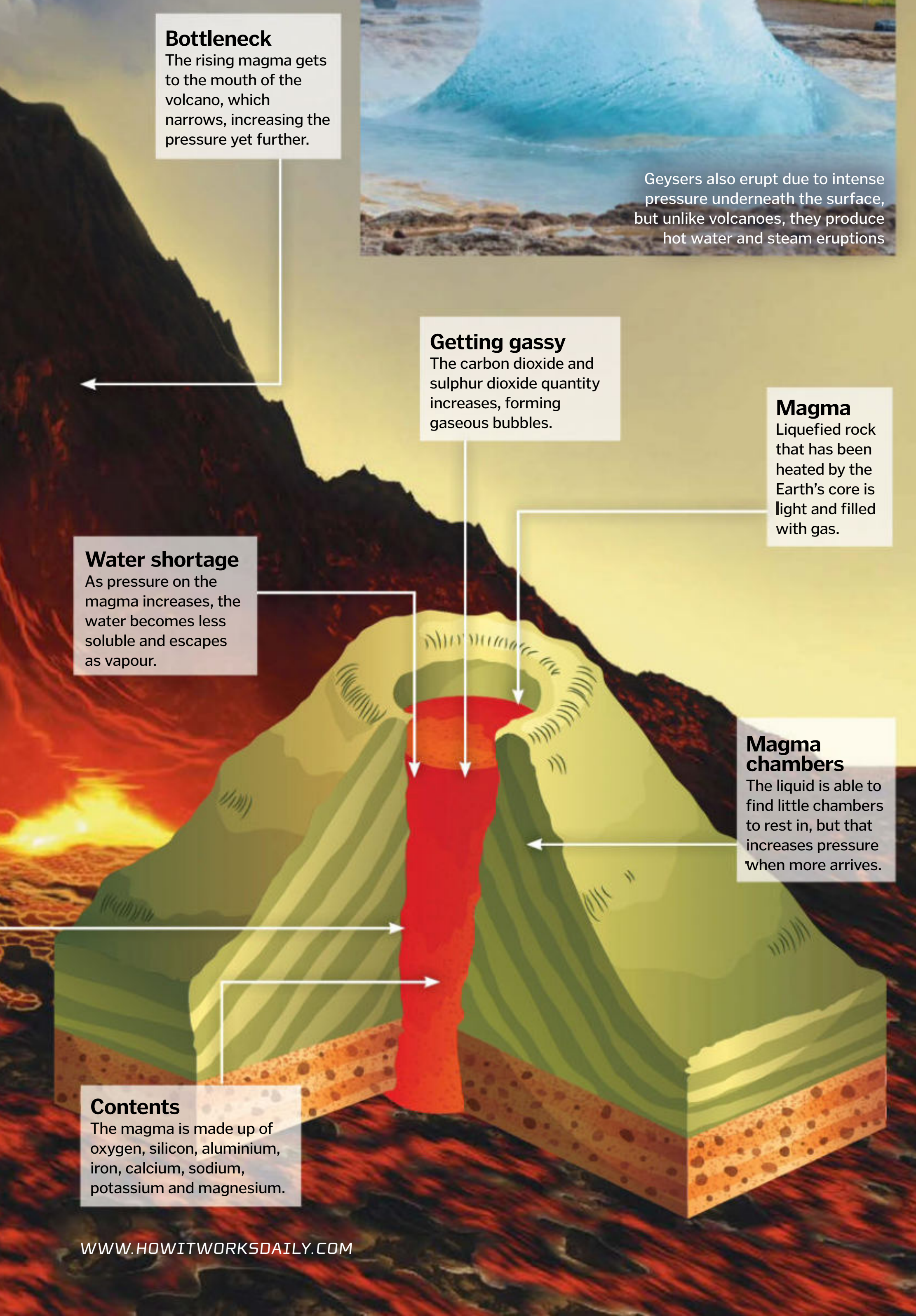
The big one
3 The biggest explosion of all time is thought to have been the Toba supereruption in Indonesia, which may have started a volcanic winter 69,000 years ago.

The biggest one
4 We Earthlings aren't the only ones to have volcanoes. Olympus Mons on Mars is a massive 25km (15.5mi) high and 624km (388mi) across.

Krakatoa
5 One of the most famous volcanic eruptions of all time was Krakatoa in 1883. The explosion could be heard over 4,800km (3,000mi) away.

DID YOU KNOW? At any one time, there are around ten volcanoes erupting around the world. Most are fairly small, though

Geysers also erupt due to intense pressure underneath the surface, but unlike volcanoes, they produce hot water and steam eruptions

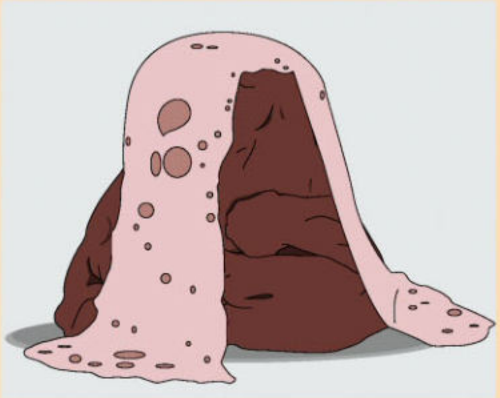


How to create your own homemade volcano

If you're itching to see something explosive in action, try making this home volcano

The mould
Stand a two-litre bottle on a baking tray and cover it in dough (flour, salt, cooking oil and water) or silver foil, sloping outward to create the volcano shape.

The magma
Pour in some warm water, red food colouring and six drops of washing detergent. This will increase the pressure inside the bottle when it comes to the eruption.



The lava
Pop in two tablespoons of baking soda and finally, slowly pour in some vinegar and take a few steps back because your homemade volcano is about to blow!

"When it comes to demolishing buildings, it would take ages to take it down piece by piece"

PLANNED EXPLOSIONS

A LOOK AT THE EXPLOSIONS WE CREATE ON PURPOSE

As a species, we are amazing at taking things that occur in nature and adapting them to be useful. We've borrowed animals' camouflaging skills, plants' photosynthesis abilities and the awesome power of the explosion is no different.

We make use of controlled explosions every day to help our cars move or get rid of buildings we no longer need. Even though gunpowder and explosive material can be really dangerous, if handled in the right way they can help us in fascinating ways.

When it comes to the behemoth task of demolishing buildings, it would take ages to take it down piece by piece or knock it down with tools. Wrecking balls create so much debris that the surrounding area could be at risk. That's why using dynamite to get rid of a skyscraper is a better idea because it means that we have some kind of say in what direction it falls down, rather than leaving it to chance as could happen with other less precise methods.

We also wouldn't be able to get anywhere at any kind of speed without the propelling power of explosions. A series of small explosions is what forms the basis of the internal combustion engine, which is what most of our cars use.

Another use is rock blasting. Whether people are trying to get through a pile of rocks to mine or rescue trapped people, rock blasting takes a massive amount of effort out of moving tons of solid rock from an area.

If we take great enough care, explosions can be among the most useful things we can take from the world around us.

3… 2… 1…

How do you go about knocking down 50 floors of building?

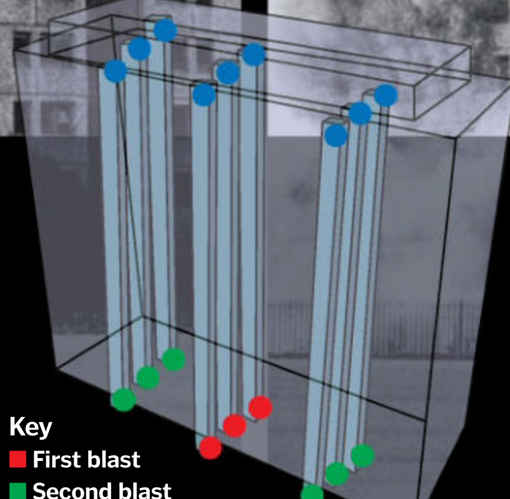
Preparation
The team behind the demolition will usually create a 3D computer model of the building to work out where the dynamite needs to be put so the building can fall safely. The easiest way to demolish a building is to let it fall to one side, but if that's not possible, they'll need to place explosives so it collapses in on itself.

Mentos and Diet Coke

Dropping the mint or fruit-flavoured sweet into a bottle of Diet Coke creates a huge eruption of foam. This is because the rough sweets disturb the liquid molecules, creating bubbles. The sweetener aspartame lessens surface tension, so it's easier for the bubbles to shoot higher out of the bottle.

How building implosions work

Three is the magic number. The positioning of the explosives is really important. You'd think that you'd just drop some dynamite at the bottom and set it off, but that could result in the building toppling to one side. Explosives are laid near the bottom, but will also be put on higher floors to break up any larger pieces of debris as the building falls. This approach creates three different demolitions, so the whole procedure doesn't rely on just one bang!



Key
First blast
Second blast
Third blast

STRANGE BUT TRUE
SWEET BURST

What caused an explosion in 1919?
A **Molasses** B **Honey** C **Crackers**

Answer:
A storage tank in Boston, USA was holding nearly 2.5 million gallons (9.5 million litres) of molasses. It suddenly exploded , shaking the nearby ground like a passing train and releasing a mighty flood of molasses into the streets.

DID YOU KNOW? The sandbox tree has fruit that explodes, sending seeds flying at up to 250km/h (155mph)

The descent
Another reason why there are three explosions is to help it fall more uniformly. The removal of a floor higher up will make it drop down onto the floors below, pushing them directly down. If a Jenga tower is toppled incorrectly from the base, it will fall to the side, but if you whip away a layer higher up, it will fall straight downward and make for a cleaner demolition.

What's in a demolition?
The material used in building demolition varies but it's usually dynamite or Research Department explosive (RDX). It needs a massive charge, so the team will use another explosive that will be detonated remotely using an electronic charge. This small explosion will trigger the main explosion, releasing nitrogen and carbon-oxide gases at a rate of 8,230m (27,000ft) per second to blow out the building's support structures.

The Hollywood explosion

If there's one thing Hollywood loves, it's an explosion. Huge fireballs are particular crowd-pleasers, but how are they created?

The iconic explosion of the Death Star in *Star Wars – Episode IV* was produced by putting a camera directly underneath a composition of sulphur, potassium nitrate and charcoal. The mixture was ignited and the fireball headed straight down toward the camera, giving the impression of a huge, outward explosion.

If you're in Hollywood and don't want to blow up a huge building, you'll use a model. Movies like *Independence Day* used a plaster model of the White House to destroy, because plaster looks a lot like concrete on screen.

It's bad news for film buffs who love a tough guy strolling away from a massive explosion: unless they've got a starting distance of around 360 metres (1,181 feet) from where an explosion starts by just 2.3 kilograms (five pounds) of explosive, they're going to end up pretty toasty!

Blasting rock
The most important stage in rock blasting is to bore a hole into the area you are attempting to blow up. This is essentially destroying a rock from the inside, usually to gain access to mining resources or to rescue people following a rock slide. After drilling a hole in the rock, you fill it with ammonium nitrate-fuel oil. When detonated, the explosion should expand in all directions.

"The team found no difference in the strength of the [brain] networks in each hemisphere"

Left or right brained?

Actually, you're neither. Discover the truth behind the way we think

It's true that the different sides of the brain perform different tasks, but do these anatomical asymmetries really define our personalities? Some psychologists argue that creative, artistic individuals have a more developed right hemisphere, while analytical, logical people rely more heavily on the left side of the brain, but so far, the evidence for this two-sided split has been lacking.

In a study published in the journal PLOS ONE, a team at the University of Utah attempted to answer the question. They divided the brain up into 7,000 regions and analysed the fMRI scans of over 1,000 people, in order to determine whether the networks on one side of the brain were stronger than the networks on the other.

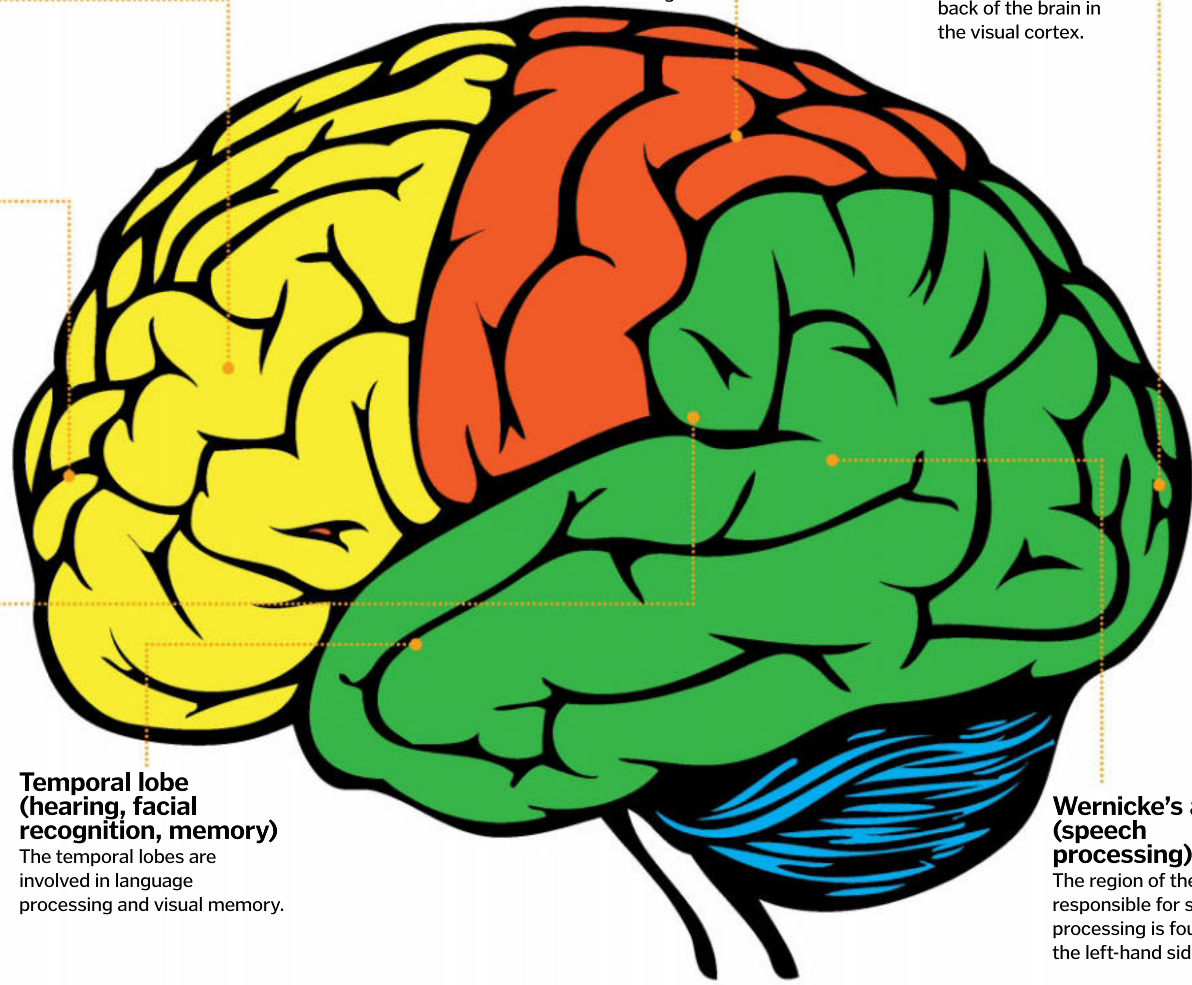
Despite the popularity of the left versus right brain myth, the team found no difference in the strength of the networks in each hemisphere, or in the amount we use either side of our brains. Instead, they showed that the brain is more like a network of computers. Local nerves can communicate more efficiently than distant ones, so instead of sending every signal across from one hemisphere to the other, neurones that need to be in constant communication tend to develop into organised local hubs, each responsible for a different set of functions.

Hubs with related functions cluster together, preferentially developing on the same side of the brain, and allowing the nerves to communicate rapidly on a local scale. One example is language processing – in most people, the regions of the brain involved in speech, communication and verbal reasoning are all located on the left-hand side.

Some areas of the brain are less symmetrical than others, but both hemispheres are used relatively equally, albeit for different things. There is nothing to say you can't be a brilliant scientist and a great artist, too.

Examining the human brain

What do the different parts of the brain actually do?



Broca's area (speech)
Broca's area is responsible for the ability to speak and is almost always found on the left side of the brain.

Frontal lobe (planning, problem solving)
At the front of each hemisphere is a frontal lobe, the left side is more heavily involved in speech and verbal reasoning, while the right side handles attention.

Auditory cortex (hearing)
The auditory cortex is responsible for processing information from the ears and can be found on both sides of the brain, in the temporal lobes.

Temporal lobe (hearing, facial recognition, memory)
The temporal lobes are involved in language processing and visual memory.

Parietal lobe (pressure, taste)
The parietal lobes handle sensory information and are involved in spatial awareness and navigation.

Occipital lobe (vision)
Incoming information from the eyes is processed at the back of the brain in the visual cortex.

Wernicke's area (speech processing)
The region of the brain responsible for speech processing is found on the left-hand side.

THE STATS
BRAINY NUMBERS

86 billion NEURONS

>100 trillion SYNAPSES

NERVE IMPULSE SPEED **100 metres per second**

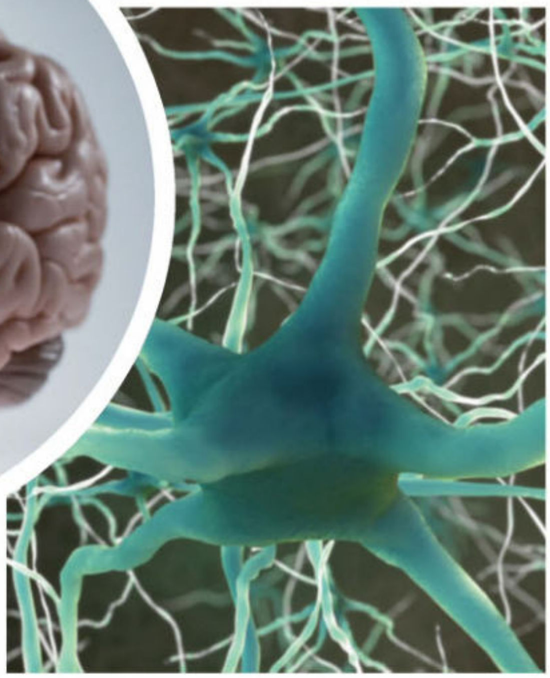
1.4kg MASS

20% OXYGEN USAGE

POWER CONSUMPTION **20W**

DID YOU KNOW? *It is a myth that we only use ten per cent of our brains; even at rest, almost all brain regions are active*

It took 82,944 computer processors 40 minutes to simulate just one second of human brain activity, it's that powerful



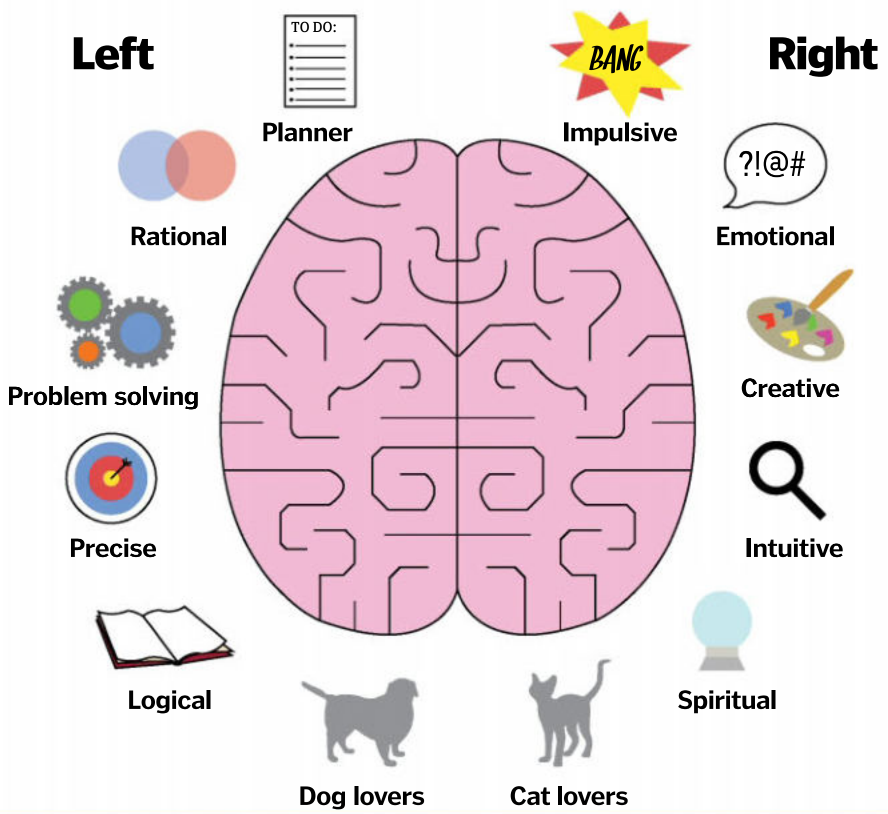
A microscopic image of the brain's extremely complex neural network

Learn more

For more on the brain and other science topics, check out the British Science Festival, which will be held from 6 to 11 September all around Birmingham. Head to www.britishsciencefestival.org for more information.

Myth-taken identity

The left vs right brain personality myth is actually based on Nobel Prize-winning science. In the 1940s, a radical treatment for epilepsy was trialled; doctors severed the corpus callosum of a small number of patients, effectively splitting their brains in two. If a patient was shown an object in their right field of view, they had no difficulty naming it, but if they were shown the same object from the left, they couldn't describe it. Speech and language are processed on the left side of the brain, but the information from the left eye is processed on the right. The patients were unable to say what they saw, but they could draw it. Psychologists wondered whether the differences between the two hemispheres could create two distinctive personality types, left-brained and right-brained.



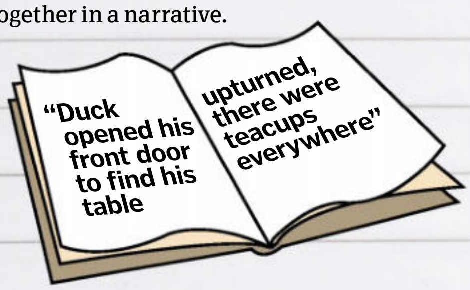
Give your brain a fun workout

1 Boost your memory

Look at this list of items for one minute, then cover the page and see how many you can remember:

Coin	Telephone	Grape
Duck	Potato	Pillowcase
Key	Teacup	Bicycle
Pencil	Match	Table

Difficult? Try again, but this time, make up a story in your head, linking the objects together in a narrative.



...You get the idea. Make it as silly as you like; strange things are much more memorable than the mundane.

2 Slow brain ageing

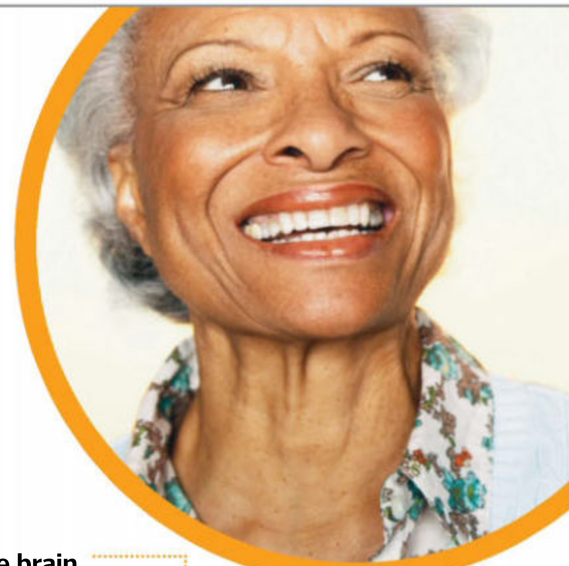
Learning a new language is one of the best ways to keep your brain active. Here are four new ways to say hello:

- Polish: Cześć! (che-sh-ch)
- Russian: Zdravstvuj (zdrah-stvooy)
- Arabic: Marhaba (mar-ha-ba)
- Swahili: Hujambo (hud-yambo)

> "Humans are able to hear things thanks to thousands of tiny hairs just inside their ears"

Curing deafness

We're getting ever closer to restoring the gift of hearing



There are more than 250 million people in the world who suffer from hearing loss or deafness, but it seems there is hope for them now.

Humans are able to hear things thanks to thousands of tiny hairs just inside their ears that vibrate when sound waves hit them. Sensory hearing loss occurs when they die or become damaged, meaning that they are no longer able to perform that action. This usually happens when the ear has been subjected to loud noises or the hair no longer regrows, often due to old age or natural degeneration.

Fortunately, scientists have been working hard to reverse that process. A recent study by British scientists has found that there is a protein contained in the body called Notch that stops new ear hair cells growing from stem cells. They have developed a drug that blocks this protein, meaning the body can regrow those crucial ear hairs.

A second experiment carried out by the University of Kansas injected a harmless virus into the ears of patients, which had a gene called Atoh1 in it, which stimulated the growth of the sensory hairs.

While we are still an awfully long way from being able to cure deafness from birth, these recent developments mean that people who have steadily lost their hearing could soon have it back, as loud and clear as ever.

Help for hearing

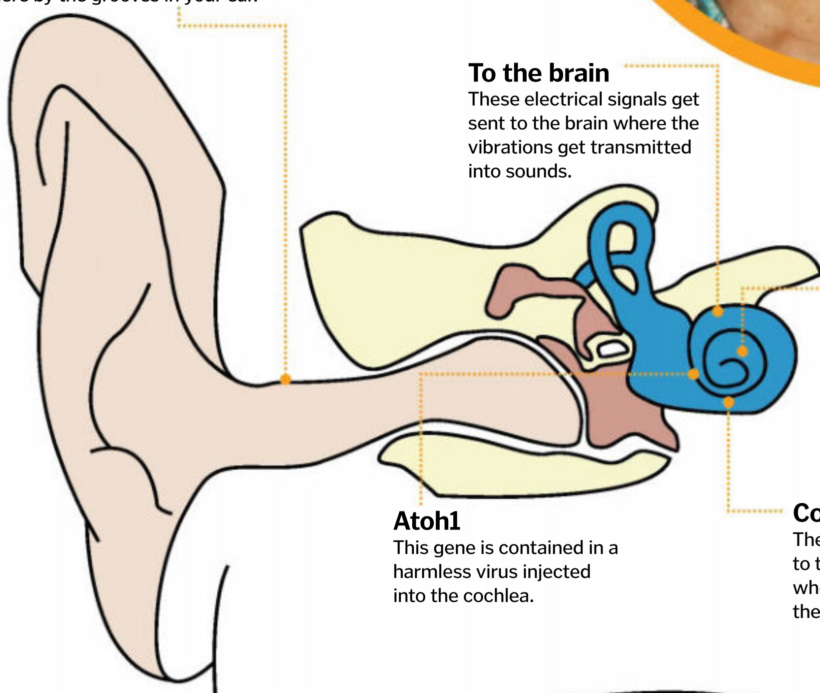
While the prospect of regrowing sensory hair cells and curing deafness is really exciting, there have been ways of helping people hear for a long while now. Ear trumpets were used in the 17th century as a popular way of helping people hear as they provided a much wider area for the sound waves to get trapped in.

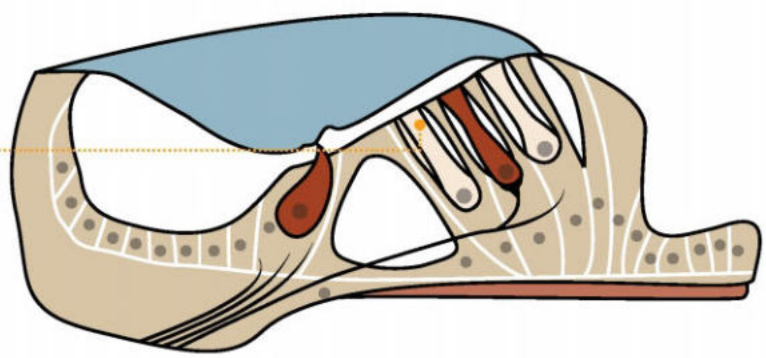
Nowadays, digital hearing aids are the norm. They are placed in the ear and a receiver registers the sound wave. A silicon chip then converts the sound waves into electrical signals, which are then released into the ear. They are basically just a way of capturing sounds the ear wouldn't have heard otherwise.

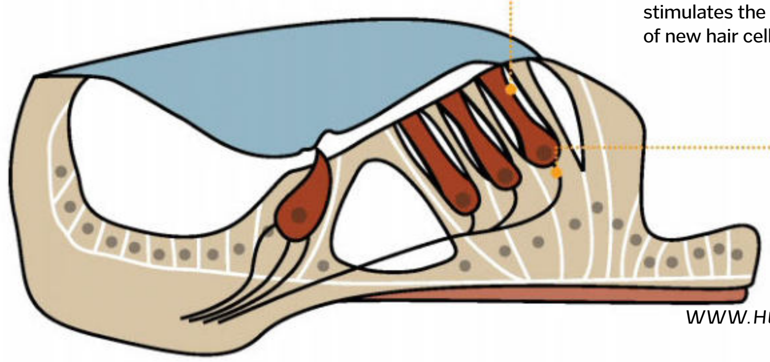
Failing that, cupping your hand behind your ear gives you an extra 12 decibels of sound, so you can try that as a small temporary boost if you're in a loud room!

How ears work

How do our ears turn invisible waves into sound?







Who do you inherit mitochondria from?

A Father B Mother C Grandparent

Answer:
The DNA within mitochondria is only from your mother's egg. The corresponding DNA from your father's sperm is destroyed after fertilisation. This means researchers can track back unchanged maternal inheritance lines many hundreds of years.

DID YOU KNOW? Mitochondrial disease occurs when mitochondria malfunction – there is a huge variety of symptoms

What powers your cells?

Discover how mitochondria produce all the energy your body needs

Mitochondria are known as the batteries of cells because they use food to make energy. Muscle fibres need energy for us to move and brain cells need power to communicate with the rest of the body. They generate energy, called adenosine triphosphate (ATP), by combining oxygen with food molecules like glucose.

However, mitochondria are true biological multi-taskers, as they are also involved with signalling between cells, cell growth and the cell cycle. Theyperform all of these functions by regulating metabolism - the processes that maintain life - by controlling Krebs Cycle which is the set of reactions that produce ATP.

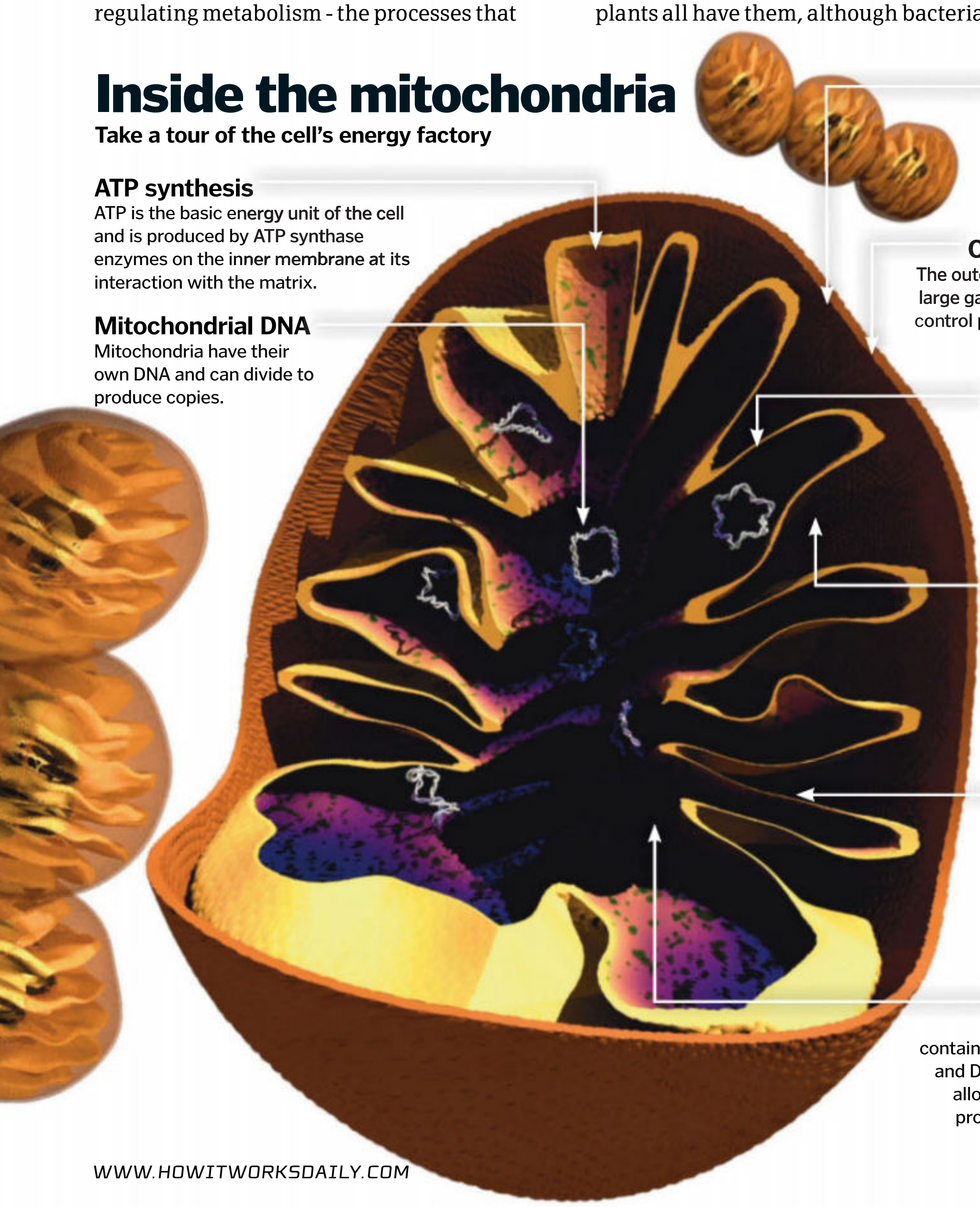
Mitochondria are found in nearly every cell in your body. They are found in most eukaryotic cells, which have nucleus and other organelles bound by a cell membrane. This means cells without these features, such as red blood cells, don't contain mitochondria. Their numbers also vary based on the individual cell types, with high-energy cells, like heart cells, containing many thousands. Mitochondria are vital for most life – human beings, animals and plants all have them, although bacteria don't.

They are deeply linked with evolution of all life. It is believed mitochondria formed over a billion years ago from two different cells, where the larger cell enveloped the other. The outer cell became dependent on the inner one for energy, while the inner cell was reliant on the outer one for protection.

This inner cell evolved to become a mitochondrion, and the outer cells evolved to form building blocks for larger cell structures. This process is known as the endosymbiotic theory, which is Ancient Greek for 'living together within.'

Inside the mitochondria

Take a tour of the cell's energy factory



ATP synthesis
ATP is the basic energy unit of the cell and is produced by ATP synthase enzymes on the inner membrane at its interaction with the matrix.

Mitochondrial DNA
Mitochondria have their own DNA and can divide to produce copies.

Phospholipid bilayer
Every mitochondria has a double-layered surface composed of phosphates and lipids.

Outer membrane
The outer membrane contains large gateway proteins, which control passage of substances through the cell wall.

Inner membrane
This layer contains the key proteins that regulate energy production inside the mitochondria, including ATP synthase.

Inter-membrane space
This contains proteins and ions that control what is able to pass in and out of the organelle via concentration gradients and ion pumps.

Cristae
The many folds of the inner membrane increase the surface area, allowing greater energy production for high-activity cells.

Matrix
The mitochondrial matrix contains the enzymes, ribosomes and DNA, which are essential to allowing the complex energy-producing reactions to occur.

Mitochondria produce fuel for everyday activities such as exercise

How many are in a cell?

The number of mitochondria in a cell depends on how active that particular cell is and how much energy it requires to function. As a general rule, they can either be low energy without a single mitochondrion, or high energy with thousands per cell. Examples of high-energy cells are heart muscles or the busy liver cells, which are active even when you're asleep, and are packed with mitochondria to keep functioning. If you train your muscles at the gym, those cells will develop more mitochondria as an adaptive mechanism to help provide energy.

> "The technology took a huge leap forward when they brought lasers into the equation"

Inside laser eye surgery

How surgeons are able to restore your sight with lasers

Lasers have been used to help people with short and long-sightedness for a couple of decades, but the practice of using incisions in a person's eye to improve their vision has been around for over 100 years.

It all started in 1898 when eye surgeons would make small cuts in the front surface of the eye (cornea), to flatten it in the middle and let light reach the retina more easily. As this technique was a bit hit-and-miss, they came up with a new technique that involved using a thin blade to slice open the cornea and create a flap. The eye surgeon would then slice a bit of tissue from the cornea to flatten it as before and then fold the flap back down.

The technology took a huge leap forward when they brought lasers into the equation. These super-precise beams were able to burn away part of the cornea without creating a flap, but this did lead to a very long and uncomfortable recovery.

Then, in 1999, LASIK entered the arena. This procedure, combining two previous methods, required a flap to be made and then the laser could get to work with shaping the stroma layer of the cornea. This allowed for more precision than ever before and vastly reduced the discomfort from the previous method.

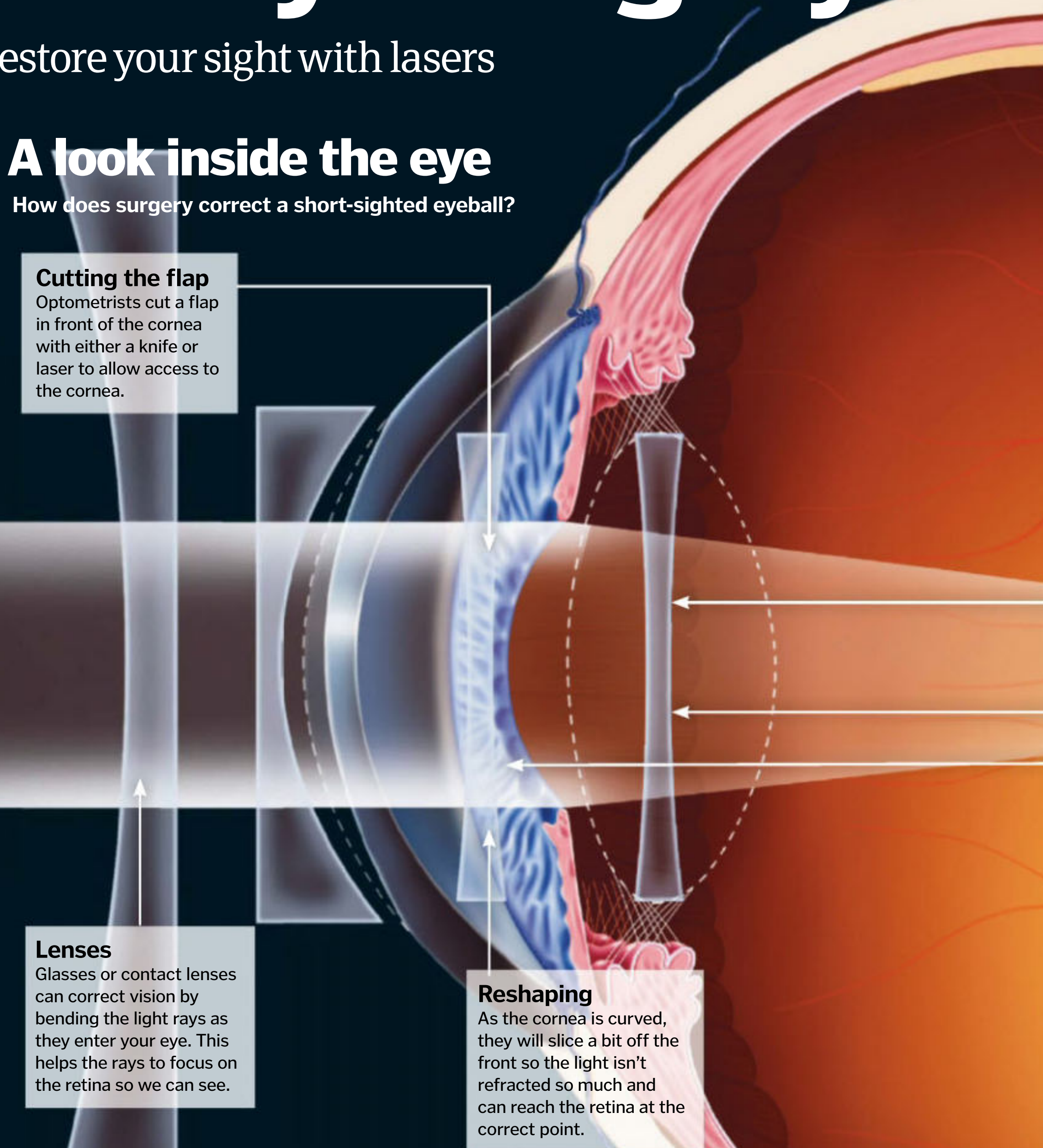
The actual surgery takes a surprisingly short amount of time. From the point at which the numbing drops get popped in, the creation of a flap, reshaping and replacing it should take between 15 and 30 minutes, with full vision returning within 24 hours.

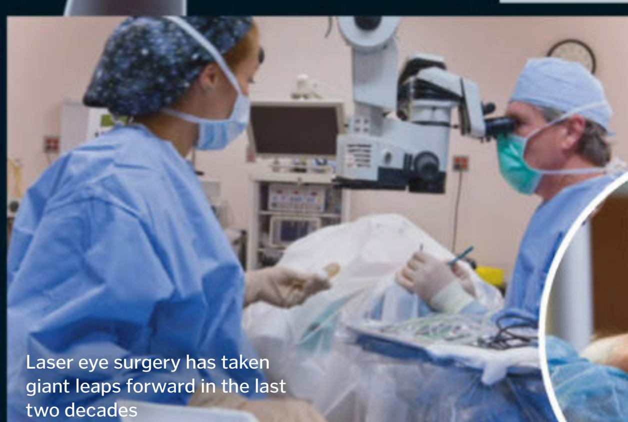
What else can laser eye surgery do?

Laser eye surgery is not limited to curing long and short-sightedness. Modern technology is also able to cure astigmatism, which happens when a person's cornea is an irregular shape, which means light doesn't enter the retina cleanly and is bounced about, resulting in blurred vision. The laser is able to reshape the cornea.
The cornea in a short-sighted eye is bent too much, so when light enters, the image gets formed too early and becomes blurry when things are far away. The opposite applies to long-sightedness, as the cornea isn't bent enough and the image hasn't been formed by the time it hits the retina.

A look inside the eye

How does surgery correct a short-sighted eyeball?





Laser eye surgery has taken giant leaps forward in the last two decades

5 TOP FACTS
EYE SURGERY

1898
1 Radial keratotomy is developed to successfully treat myopia for the first time, using careful incisions into the eye to adjust their focus point.

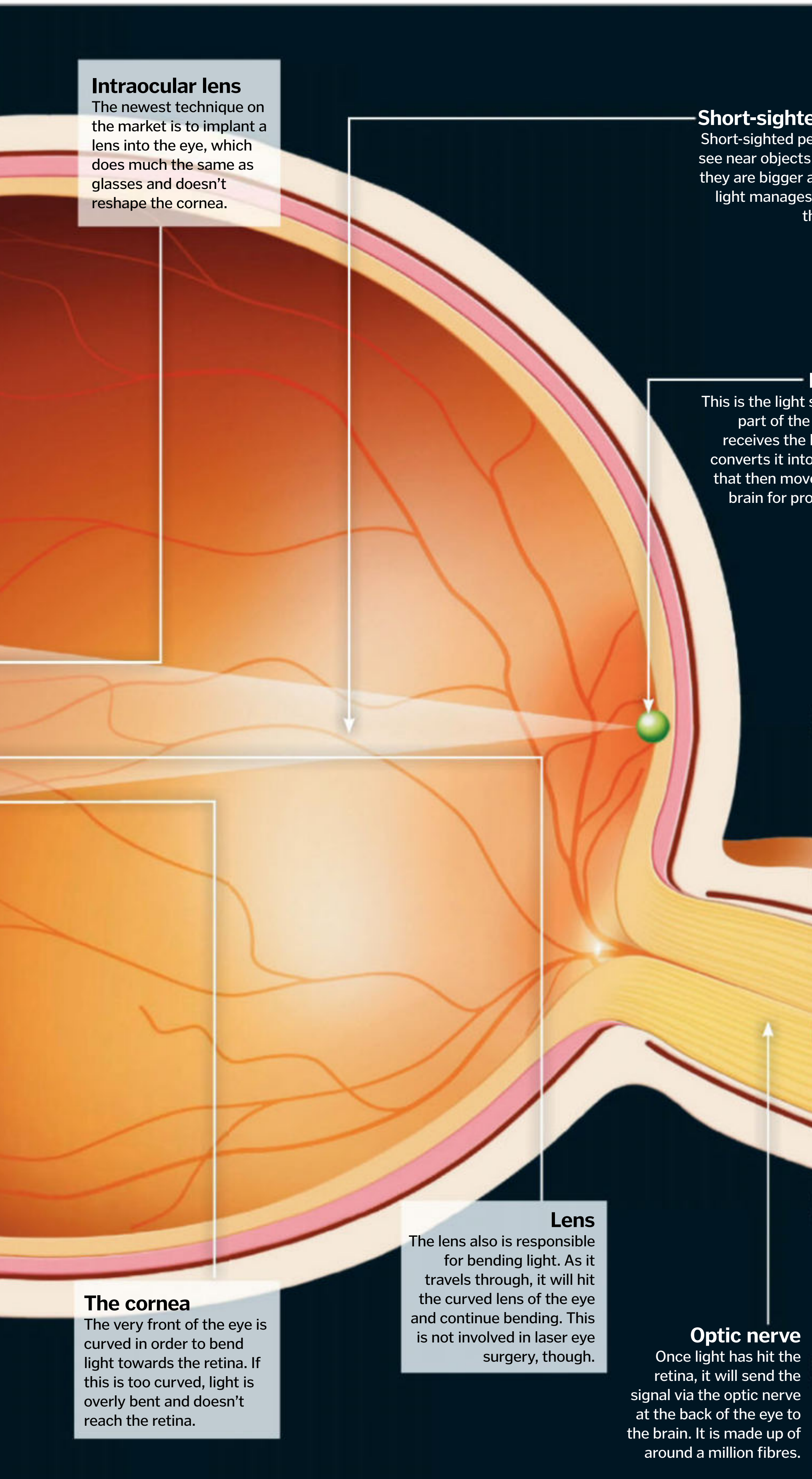
1960s
2 The procedure of radial keratotomy is considerably improved from earlier methods, with greater accuracy, but results are still not guaranteed.

1990s
3 Automated Lamellar Keratoplasty (ALK) is the first eye-surgery process that creates a flap of skin for easier corneal access, making the process faster.

1995
4 Laser-eye surgery is officially approved for use for the first time. The beam goes straight into the cornea to remove small sections of it.

1999
5 Laser-Assisted in-SItu Keratomileusis uses the accuracy of the laser and comfort of the ALK method.

DID YOU KNOW? *Eye surgeons are called ophthalmologists, which is Greek for 'study of eyes'*



Intraocular lens
The newest technique on the market is to implant a lens into the eye, which does much the same as glasses and doesn't reshape the cornea.

Short-sightedness
Short-sighted people can see near objects because they are bigger and more light manages to reach the retina.

Retina
This is the light sensitive part of the eye that receives the light and converts it into a signal that then moves to the brain for processing.

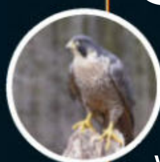
Lens
The lens also is responsible for bending light. As it travels through, it will hit the curved lens of the eye and continue bending. This is not involved in laser eye surgery, though.

The cornea
The very front of the eye is curved in order to bend light towards the retina. If this is too curved, light is overly bent and doesn't reach the retina.

Optic nerve
Once light has hit the retina, it will send the signal via the optic nerve at the back of the eye to the brain. It is made up of around a million fibres.

An eye for numbers
We've all heard about 20/20 vision, but what exactly does that mean? Well, eye specialists have worked out how tall letters have to be for a normal eye to be able to see them at 20 feet (6.1 metres). Someone with 20/20 vision can see letters of that height from 20 feet, meaning their vision is just as expected. Someone with 20/40 vision can see something at 20 feet that a person with normal vision can see at 40 feet (12.2 metres). So, the bigger the second number, the worse the vision.

Scale of sight



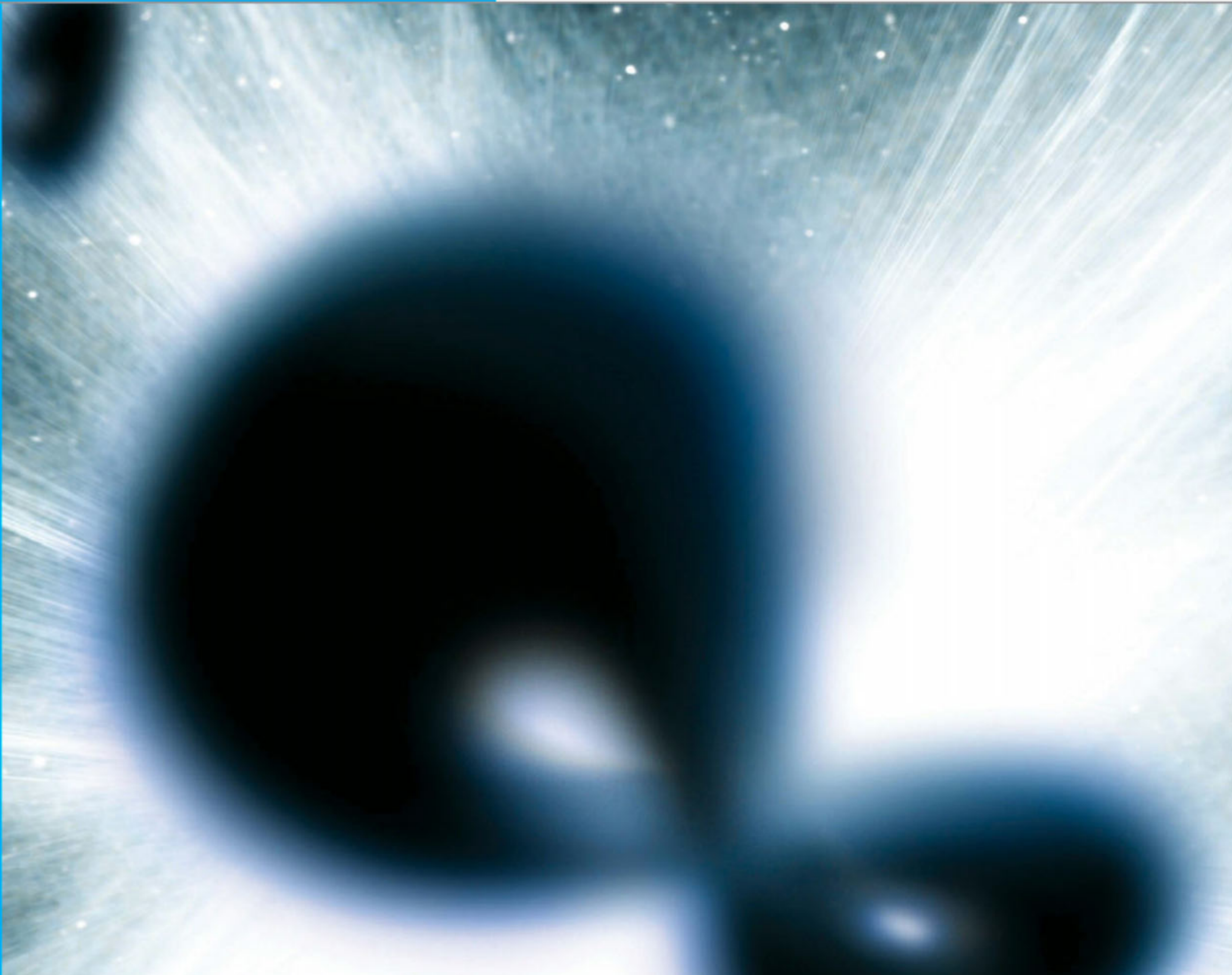
20/2
VISION OF A FALCON, OVER EIGHT TIMES BETTER THAN A HUMAN

20/20
NORMAL VISION – MINIMUM REQUIREMENT TO BE A FIGHTER PILOT

20/40
WORST YOUR EYES CAN BE AND STILL BE ALLOWED TO DRIVE

20/80
STILL JUST ABOUT ABLE TO READ NEWSPAPER HEADLINES

20/200
LEGALLY BLIND – HOWEVER, YOU STILL CAN SEE STOP SIGNS



Dark history

Hubble has shown us more of the universe than we ever expected

The Hubble Space Telescope has successfully mapped a cross-section of dark matter in the universe to a distance of 6.5 billion light years. Astronomers measured the shape of galaxies in images of this cross-section – the huge amount of dark matter acts as a gravitational lens, warping the light from the galaxies. The degree of lensing shows how much dark matter is present. The results showed that dark matter has become clumpier with time, as gravity pulls it and ordinary matter into a giant web across the universe.

STRANGE BUT TRUE
THAT'S DARK, MAN

What is VIRGOHI21?

A The astrological star sign of dark matter
B A dark galaxy made almost totally of dark matter
C The study of dark matter in the constellation Virgo

Answer:
VIRGOHI21 is a galaxy made almost entirely out of dark matter, discovered by astronomers at Cardiff University in 2005. VIRGOHI21 contains a thousand times more dark matter than baryonic matter, has no stars and is a tenth of the size of the Milky Way.

DID YOU KNOW? *New research from 2014 suggests that dark matter might be hiding in microscopic black holes*

THE MYSTERY OF DARK MATTER

Hunting for the invisible mass that makes up 85 per cent of matter in the universe

Out there in the universe, something is going on that we're not able to fully explain. Over three billion light years away from Earth, two great clusters of galaxies are colliding. The stars in both are relatively unaffected in the melee, but clouds of hot, X-ray emitting gas are crashing into one another, stitching the two galaxy clusters into one new one: meet the Bullet Cluster, one of the most energetic events in the cosmos. Yet amid the epic confrontation of the clusters, something mysterious lurks, something for which the only name we have is 'dark matter'.

Within the Bullet Cluster we can see the galaxies. We can see the gas, which actually makes up most of the mass that emits light, more than even the galaxies. But there is a completely invisible component – dark matter – yet its presence is perhaps the most crucial.

Dark matter's name implies that this mysterious substance is dark, but it is more than that – it is invisible, refusing to emit or absorb any forms of light or radiation that could reveal its existence and end its game of hide-and-seek. It passes straight through ordinary matter. We cannot smell, taste, touch or see it. What we do know is that it accounts for 27 per cent of all the mass and energy within the universe (normal matter is only five per cent and dark energy, which is the mysterious force accelerating the expansion of the universe, makes up the remaining 68 per cent) and it's likely to be made of some form of undiscovered subatomic particle.

"Little is known about it and all that the numerous searches for dark matter particles have done is rule out various hypotheses, but there have never been any 'positive' results", says astrophysicist Maxim Markevitch, who has carefully studied the Bullet Cluster for the effects of dark matter using NASA's Chandra X-ray Observatory.

However, there is one way in which it grabs our attention, which is through the force of gravity. One of the effects of this is clearly

> *"If you imagine the ball is a galaxy and the rubber sheet as space, you can see how mass bends space"*

played out in the Bullet Cluster. It is this that allows astronomers to work out where the dark matter in the Bullet Cluster is located, even though we cannot even see it.

Albert Einstein's General Theory of Relativity described how mass can bend space. Some people like to use the analogy of a cannonball on a sheet of rubber - the cannonball causes the sheet to sag. If you imagine the ball is an object like a galaxy or a star and the rubber sheet as space, you can see how mass bends space. However, light prefers to take straight paths through the universe, so what happens when it arrives at a region of space that has been warped in this manner? The light will follow the path of curved space, bending its trajectory. In this way a massive object in space can act like a lens, bending and magnifying light. This effect was predicted by Einstein nearly 100 years ago and we call these gravitational lenses.

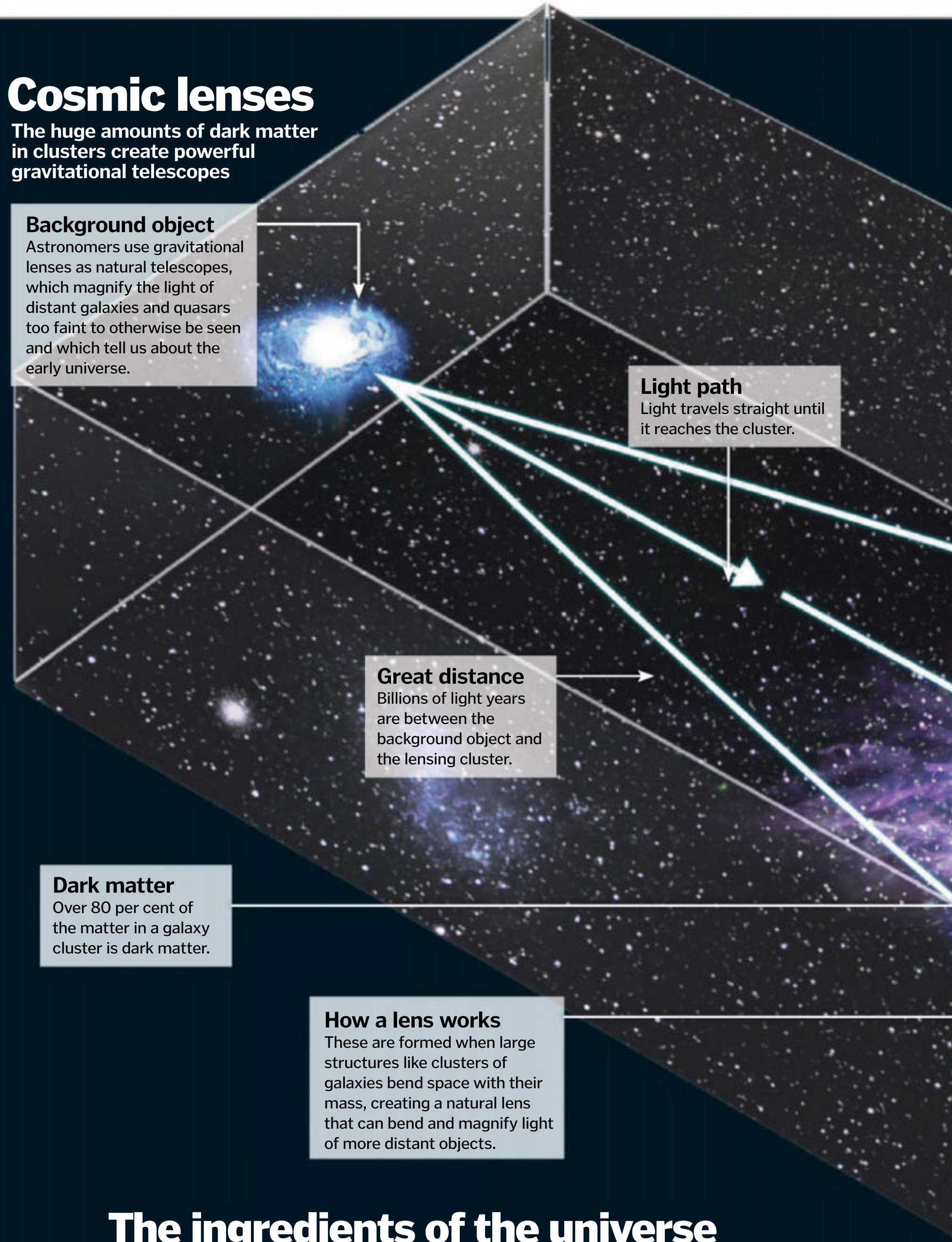
Because galaxy clusters are so huge, they create formidable gravitational lenses. They can magnify the light of even more distant galaxies, but it is not a clear image, rather distorted arcs or smudges of light and occasionally a complete ring. We can see gravitational lensing by the Bullet Cluster, magnifying the light of distant galaxies. But when scientists analysed the gravitational lens, they found something stunning – the lensing effect was too strong to be accounted for by the mass of only the galaxies and the gas. There must be some other type of mass there, hidden. This is dark matter. From the pattern of the lensing, it is possible to work out where the dark matter in the cluster is, which has lead to another remarkable discovery. As the clusters collided, the galaxies and the gas have begun to merge, but the dark matter surrounding each cluster has slid silently through, not interacting with anything at all.

The Bullet Cluster was not the first time we saw the effects of dark matter. That discovery goes all the way back to 1933 when famous astronomer Fritz Zwicky at the California Institute of Technology (Caltech) noticed that galaxies orbiting around the edge of galaxy clusters were moving faster than they should.

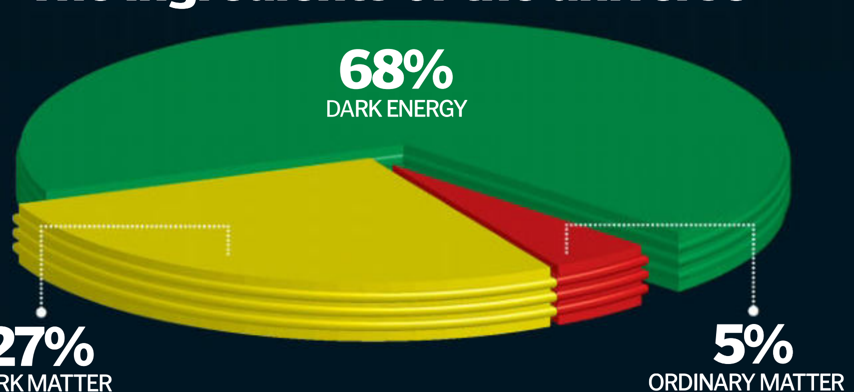
Why should they be moving at a particular speed? In the 17th century, Johannes Kepler devised his laws of orbital motion, the third one being that "the square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit." In

Cosmic lenses

The huge amounts of dark matter in clusters create powerful gravitational telescopes



The ingredients of the universe



KEY DATES

A BRIEF HISTORY OF DARK MATTER

1930s Fritz Zwicky postulates the existence of dark matter to explain the motion of galaxies in clusters.

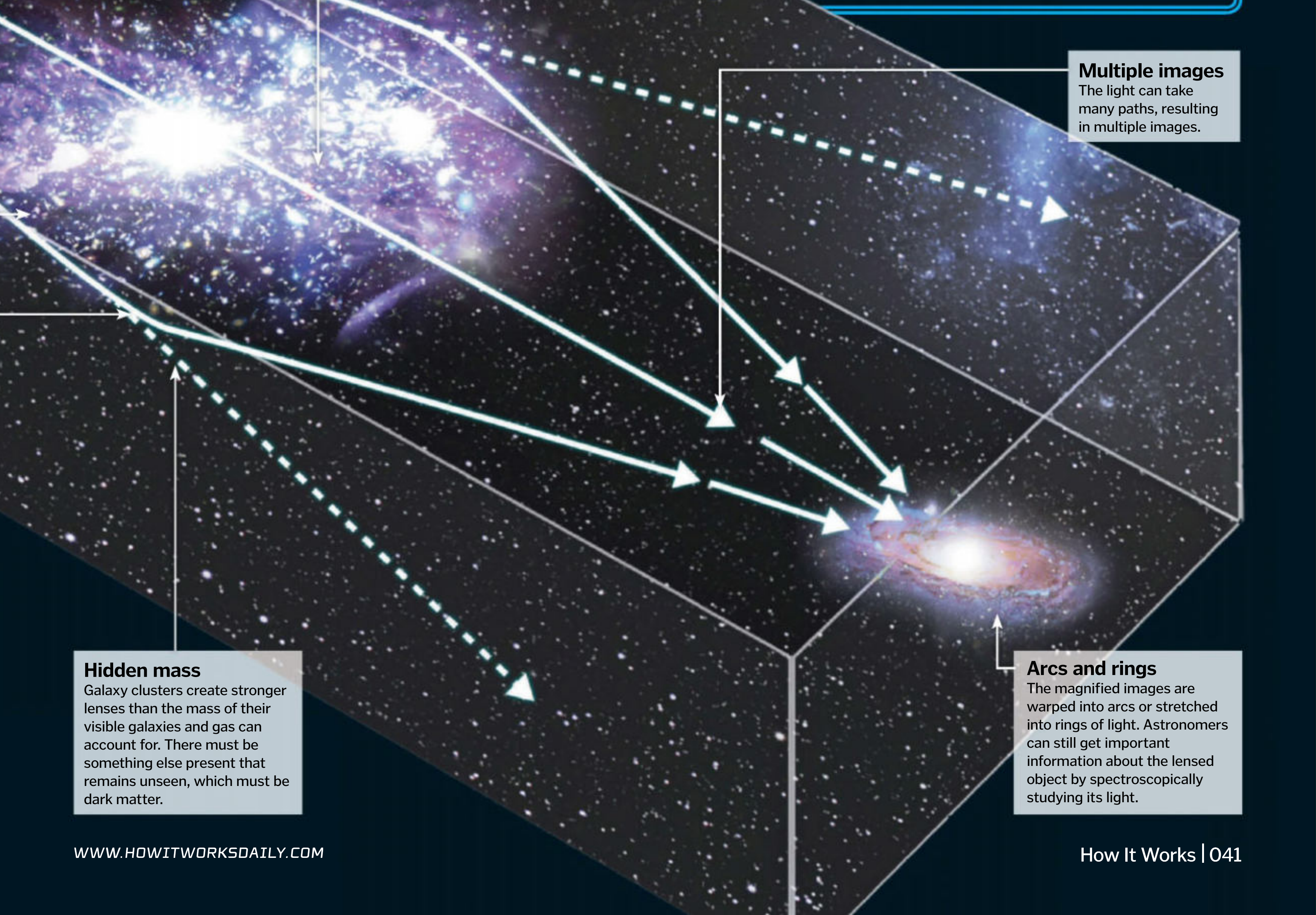
1970s Astronomer Vera Rubin finds evidence for the existence of dark matter by studying the motion of stars in galaxies.

2003 NASA's Wilkinson Microwave Anisotropy Probe reveals 24 per cent of the universe is made from dark matter.

2006 Studies of the Bullet Cluster reveal the first evidence for how dark matter causes a gravitational lens.

2013 ESA's Planck mission refines the amount of dark matter as 26.8 per cent of the universe.

DID YOU KNOW? *Dark matter exists in our Milky Way galaxy, forming a giant halo inside which our galaxy is embedded*



Magnifying lens
Space is curved by the cluster, so light follows a curved path.

Galaxies
Galaxy clusters can contain hundreds or thousands of galaxies.

Multiple images
The light can take many paths, resulting in multiple images.

Hidden mass
Galaxy clusters create stronger lenses than the mass of their visible galaxies and gas can account for. There must be something else present that remains unseen, which must be dark matter.

Arcs and rings
The magnified images are warped into arcs or stretched into rings of light. Astronomers can still get important information about the lensed object by spectroscopically studying its light.

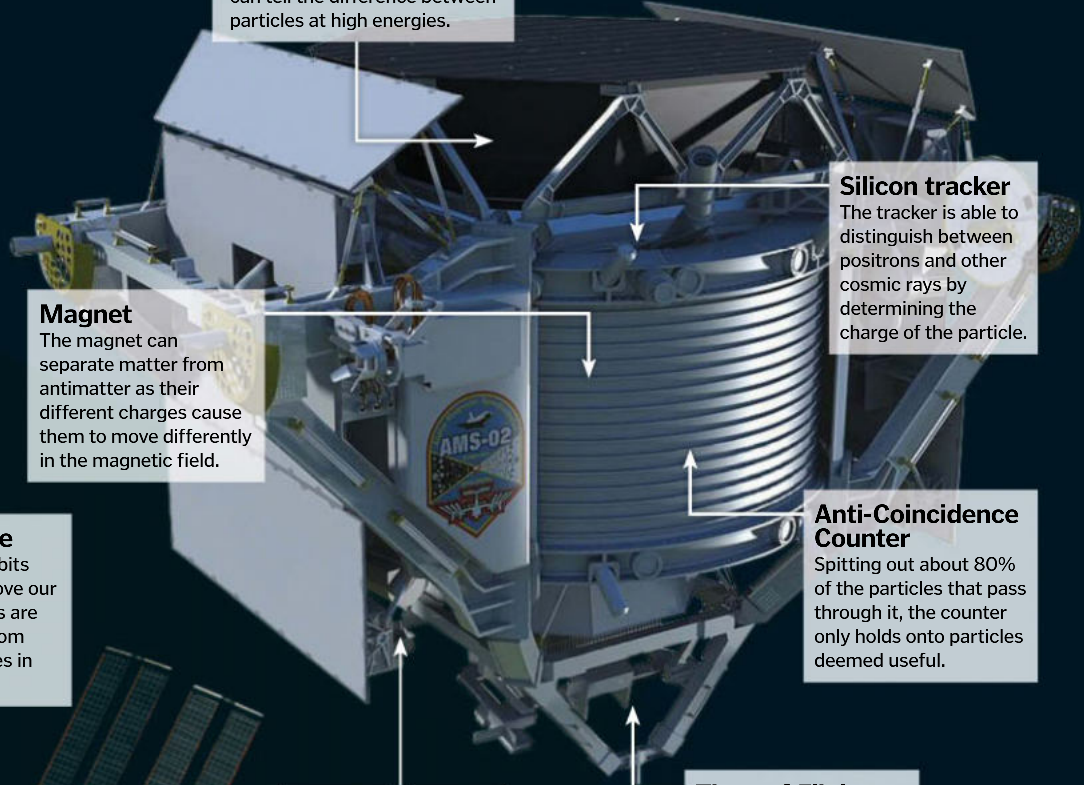
Expanding universe

Gravity and dark energy are engaged in a war for the universe. Gravity, primarily from dark matter but also ordinary matter and black holes, is trying to slow and reverse the expansion of the universe. Meanwhile, dark energy is trying to accelerate it and push the many galaxies that occupy it, away from us. Until eight billion years ago gravity was winning, but now dark energy is in ascendancy, permeating its every pore.

> "Physicists describe these particles as WIMPs, which stands for Weakly Interacting Massive Particles"

The Alpha Magnetic Spectrometer

Scientists are attempting to detect evidence for dark matter in an experiment called the Alpha Magnetic Spectrometer (AMS) on board the International Space Station. It is designed to detect charged particles called positrons, a type of antimatter, which are thought to be emitted at certain energies when two dark matter particles collide. In 2013, scientists studying the data from AMS revealed it had detected more than 400,000 positrons at those energies, strongly hinting they were from dark matter, although there was not enough information to be certain.



Transition Radiation Detector
Using X-rays to distinguish positrons (antimatter) from electrons (matter), this detector can tell the difference between particles at high energies.

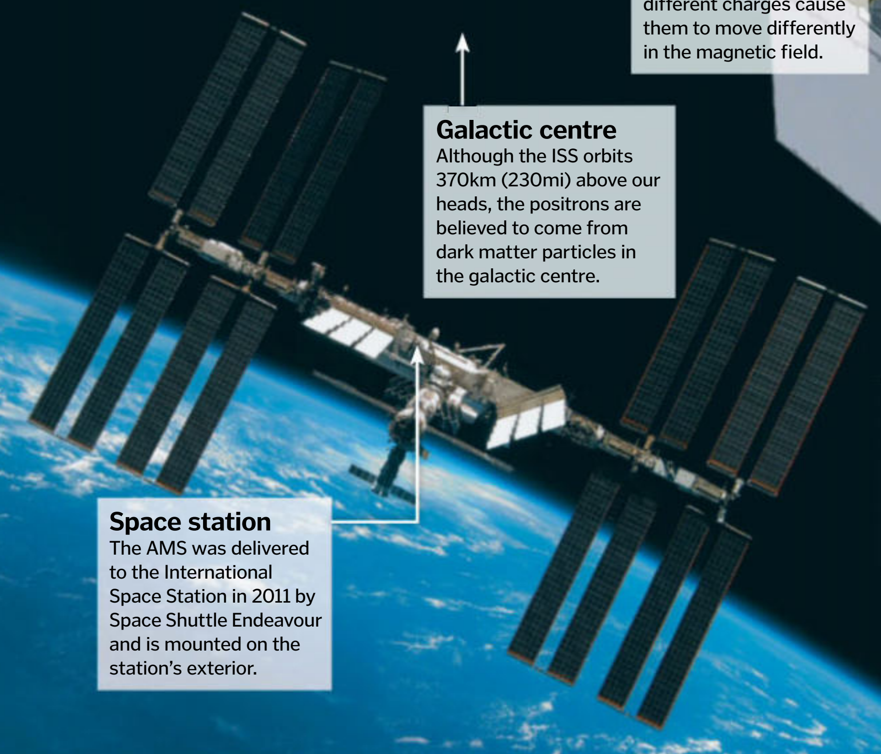
Silicon tracker
The tracker is able to distinguish between positrons and other cosmic rays by determining the charge of the particle.

Magnet
The magnet can separate matter from antimatter as their different charges cause them to move differently in the magnetic field.

Anti-Coincidence Counter
Spitting out about 80% of the particles that pass through it, the counter only holds onto particles deemed useful.

Electronics
Signals detected by the AMS's many particle detectors are converted into digital so they can be analysed by computers.

Time-of-Flight System
Acting as the AMS's stopwatch, this instrument is able to measure the time it takes for a particle to pass through, calculating its velocity.



Galactic centre
Although the ISS orbits 370km (230mi) above our heads, the positrons are believed to come from dark matter particles in the galactic centre.

Space station
The AMS was delivered to the International Space Station in 2011 by Space Shuttle Endeavour and is mounted on the station's exterior.

other words, the farther from the Sun, and therefore the centre of mass of the Solar System, the slower a planet orbits. This should also be the case for galaxies orbiting galaxy clusters, but Zwicky found that galaxies on the edges of clusters were orbiting just as fast as those closer in. This implied there must be some unseen mass in the cluster helping things along with its gravity. He called this dark matter, but his idea was generally ignored. It was only in the 1970s when astronomer Vera Rubin of the Carnegie Institution for Science noticed the same problem with the orbits of stars and gas near the edges of galaxies. This time the problem was noticed and today dark matter is one of the biggest puzzles of cosmology. Dark matter now forms an integral part of our models of how galaxies grow – we envisage galaxies in halos of dark matter, which is spread across the universe in a great cosmic web, pulling matter toward it and making galaxies and clusters expand.

The Bullet Cluster holds the best evidence for dark matter, but astronomers and particle physicists seeking to shed light on this substance are building new experiments to try to catch dark matter so we can finally find out what it is. Although evidence from space suggests that dark matter does not interact with ordinary matter on large scales, physicists suspect that on the scale of individual particles, dark matter sometimes does interact. There must be trillions of these particles passing through us every moment, but the interactions are so rare that scientists may have to wait years to see one. Physicists describe these particles as WIMPs, an abbreviation that stands for Weakly Interacting Massive Particles.

In order to trap a dark matter particle in the act, most experiments take place far

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

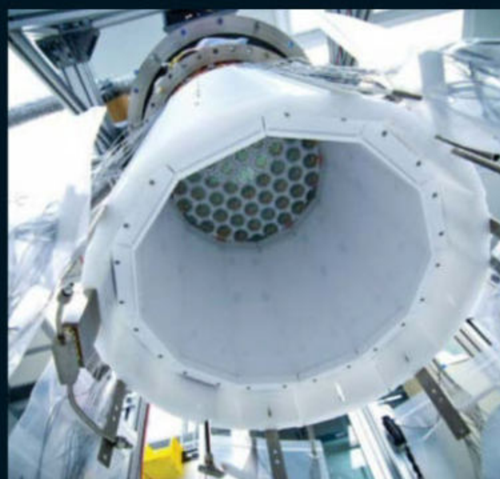
A detector on the ISS hunting for dark matter

www.howitworksdaily.com

DID YOU KNOW? *Scientists believe dark matter particles are likely so light that the LHC would be able to produce them*

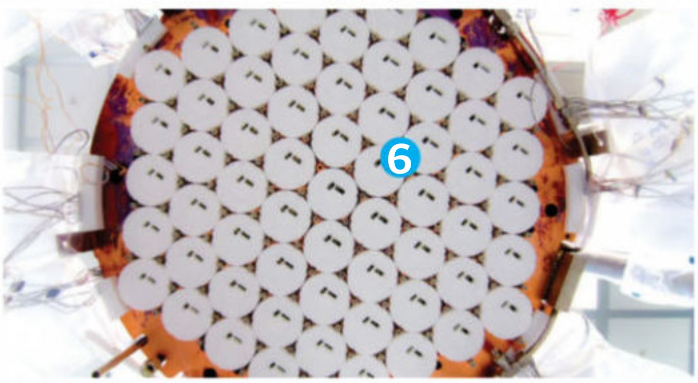
Dark matter is for WIMPs

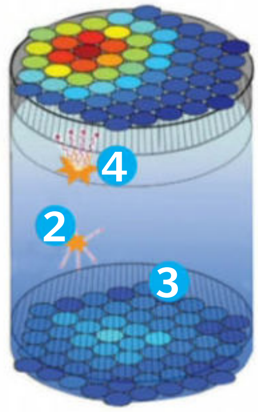
The Large Underground Xenon (LUX) experiment is buried deep beneath South Dakota, now home to the Sanford Underground Laboratory. It consists of a large tank filled with 370 kilograms (816 pounds) of liquid xenon and works on the assumption that dark matter is made of Weakly Interacting Massive Particles, or WIMPs. Occasionally a WIMP should interact with a xenon atom, emitting electrons and ultraviolet light. LUX has been working since 2012 but so far has found no evidence for WIMPs, but this has allowed scientists to constrain their models to narrow the search.



Going underground

The Large Underground Xenon experiment is searching for dark matter in South Dakota





1 Liquid xenon
Some theories on dark matter suggest it could occasionally interact with atoms such as xenon.

2 Interaction
During the interaction, the xenon atoms recoil and an electron and a UV photon are emitted.

3 Ultraviolet
At a wavelength of 175nm, the UV photons are detected by sets of photomultiplier tubes.

4 Electrons
The electrons drift to the top of the tank where they are electrically stimulated to emit visible light.

5 Tank
The experiment is shielded inside an 8x6m (26.2x19.7ft) water tank that keeps out external radiation.

6 Light sensors
Two sets of photomultiplier tubes, 122 in all, are arranged at the top and bottom of the experiment.

7 Cryostat
The experiment has to be kept cold for xenon to remain liquid, cooling LUX to -120°C (-184°F).

underground, away from any cosmic ray radiation on the surface that could contaminate the results. Experiments such as the Cryogenic Dark Matter Search in a mine in Minnesota in the United States have freezing cold detectors, cooled to fractions of a degree above absolute zero, search for the heat produced when a WIMP collides with an atom of a substance such as germanium. Another experiment, the Large Underground Xenon (LUX) dark matter detector is located 1.6 kilometres (one mile) under the Black Hills of South Dakota, USA. It contains tanks of liquid xenon for WIMPS to interact with, the interaction producing signature radiation that can be detected.

The hunt for dark matter also takes place in space. On rare occasions dark matter particles could collide and annihilate each other, releasing an antimatter particle known as a positron (the anti-particle to the negatively charged electron), but because there is so much dark matter in space, particularly dense close to the centre of the galaxy, there should be a steady stream of positrons. Now an experiment on the International Space Station, the Alpha Magnetic Spectrometer, may have detected some of these positrons.

Some astronomers think we shouldn't be searching for dark matter at all, as they don't believe it even exists. Concerned that dark matter theory adds more complexity to the universe than necessary, they argue that the gravitational effects we infer as being down to dark matter suggest we simply need to tweak the laws of gravity instead. As a result, dark matter now has a theoretical rival called Modified Newtonian Dynamics, or MOND. Will the theory of dark matter be usurped or vindicated? As time goes on, the chances of experiments detecting dark matter will increase, so it may soon come into the light.

"Astronomers detect transits of exoplanets across stars and have found over 1,000 alien worlds this way"

The secrets of transits

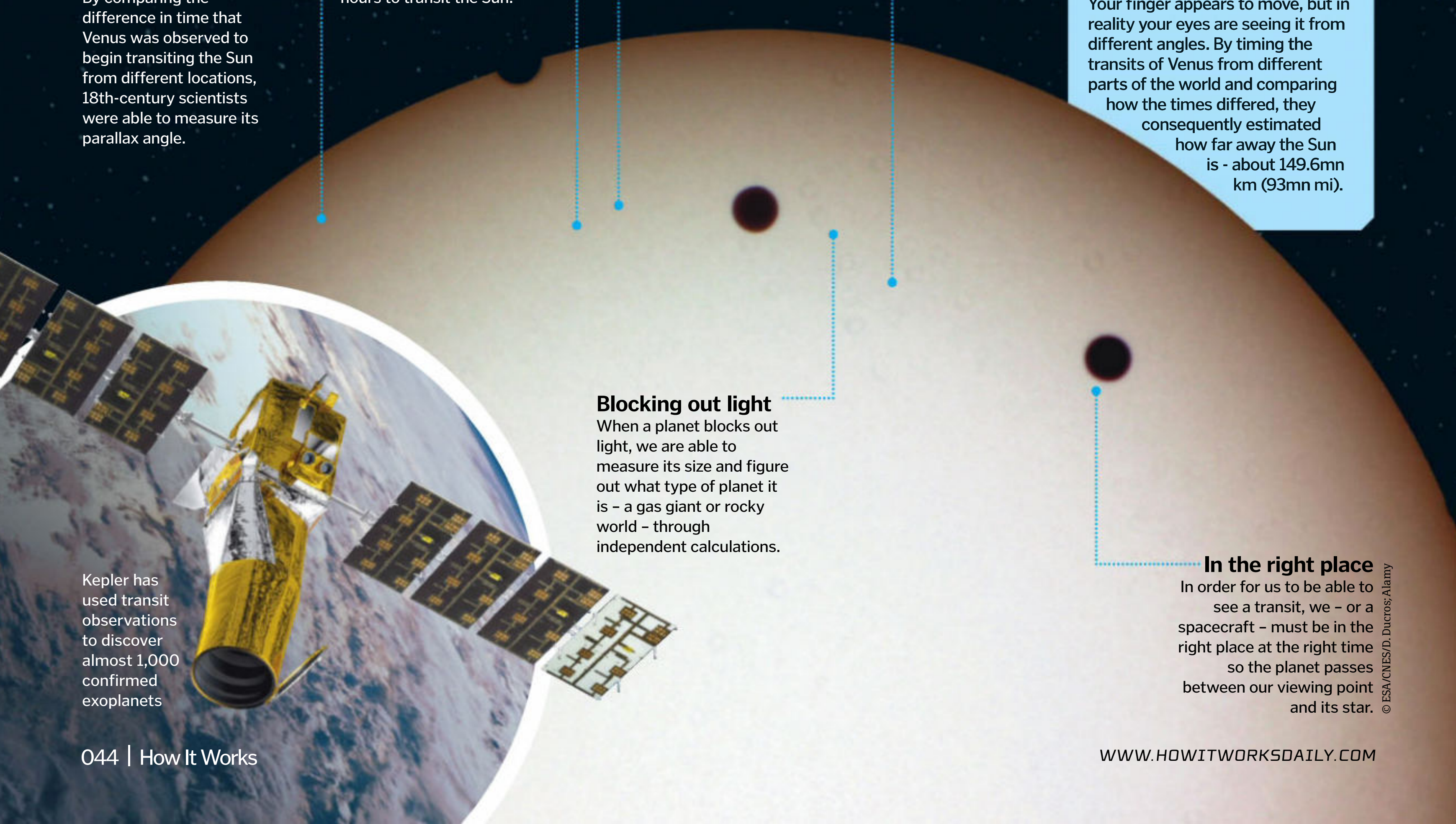
From the planet Venus to alien worlds hundreds of light years away, transits help inform us about our place in the universe

Twice every century the planet Venus does something extraordinary and appears to move, or 'transit', across the face of the Sun. It is a rare alignment of Earth's orbit with Venus' and the Sun, but in the 18th century scientists used transits of Earth's hellish cousin to measure the size of the Solar System. The most recent transits of Venus in 2004 and 2012 had relatively little scientific importance, but transits of other planets are extremely significant today. These are not transits of other planets in our Solar System, but in other star systems. Astronomers detect transits of exoplanets across stars and have found over 1,000 alien worlds this way.

As the stars are so far away, planet hunters like the Kepler space telescope can't take a picture of the exoplanet's silhouette like astronomers could for Venus. Instead they monitor how much of the starlight the planet blocks as it moves across the face of its star. Kepler is able to detect dips in the star's light as small as 0.01 percent. The amount of light blocked reveals how big the exoplanet is, the length of time it takes to transit tells the astronomers what orbit the planet is on and how far away it is from its star. With this information, astronomers can work out the planet's temperature and what kind of planet it is. Astronomers have not yet found Earth's twin, but such a discovery may not be too far away.

Transit of Venus

What are we seeing through the telescope?



Measuring angles
By comparing the difference in time that Venus was observed to begin transiting the Sun from different locations, 18th-century scientists were able to measure its parallax angle.

Eight-hour transit
The speed at which a planet transits a star tells us how far from the star the planet is, assuming we know how big the star is. Venus takes less than eight hours to transit the Sun.

Solar observing
Members of the public were able to view the recent Venus transits using solar telescopes or safe solar projection.

Out in the universe
Transits don't just happen when Venus passes across the Sun, astronomers find exoplanets by watching them move across the face of their star.

Blocking out light
When a planet blocks out light, we are able to measure its size and figure out what type of planet it is – a gas giant or rocky world – through independent calculations.

In the right place
In order for us to be able to see a transit, we – or a spacecraft – must be in the right place at the right time so the planet passes between our viewing point and its star.

Kepler has used transit observations to discover almost 1,000 confirmed exoplanets

Sizing up the Solar System

Scientists took on the task of calculating the scale of the Solar System by observing the transits of Venus in 1761 and 1769, using a clever method called parallax. To see how this works, hold your index finger up about a foot in front of your face. Close one eye, then open it and close the other. Your finger appears to move, but in reality your eyes are seeing it from different angles. By timing the transits of Venus from different parts of the world and comparing how the times differed, they consequently estimated how far away the Sun is - about 149.6mn km (93mn mi).

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1. NEW

Spirit
Both the Spirit and Opportunity crafts have found evidence of hydrothermal vents, ancient lakes of acid and evidence of wind on Mars.

2. NEWER

Curiosity
Locating ancient waterbeds and digging into the Martian surface have helped the Curiosity to reignite humanity's interest in the Red Planet.

3. NEWEST

Hopper
Using legs to traverse the rough environment instead of slow-rolling wheels, it is predicted the Hopper will make new discoveries at a rapid rate.

DID YOU KNOW? *The first manned mission to Mars is planned to launch as early as 2030*

The Mars Hopper

The Martian vehicle that will hop, skip and jump its way around the Red Planet

British scientists have designed a robot that could roam the Red Planet by jumping over 0.8 kilometres (half a mile) at a time. The Mars Hopper will tackle the rocky landscape by leaping over obstacles.

The Hopper measures 2.5 metres (8.2 feet) across and weighs 1,000 kilograms (2,205 pounds), which is slightly more than NASA's Curiosity rover. One hop could launch the vehicle up to 900 metres (2,953 feet) at a time. To achieve this, a radioactive thermal capacitor core will provide thrust through a rocket nozzle. The Martian atmosphere, thick in carbon dioxide, would provide the fuel as it is compressed and liquefied within the Hopper.

If successful, the Hopper would allow rapid exploration of Mars with tricky terrains like Olympus Mons and other hills, craters and canyons much easier to navigate. On current vehicles such as the Exploration rovers, the wheels have become stuck on slopes and the sandy, rocky texture of the planet's surface. The Hopper will use magnets in its four-metre (13-foot) leg span to allow it to leap again and again. The magnets will create an eddy current to produce a damping effect.

Proposed by experts from the company Astrium and the University of Leicester, the concept was first designed in 2010. A slight issue lies in the rate of CO_2 gathering, with the current system taking several weeks to completely fill the fuel tank. However, the vehicle will more often than not be at a standstill as it thoroughly scours the Martian landscape, so this should not pose an immediate problem.

The first-ever spacecraft to orbit Mars, NASA's Mariner 9

Martian exploration programmes

The first craft to attempt to explore Mars was launched way back in 1960 when the USSR's 1M spacecraft failed to leave Earth's atmosphere. After various unsuccessful launches by the USA and the Soviet Union, NASA's Mariner 9 became the first craft to orbit the planet in 1971. In 1975 the Viking 1 lander was the first to successfully touch down on the surface. The USSR managed to orbit Mars only weeks after the Mariner with their Mars 2 spacecraft but have not yet landed on the planet. The most recent lander is NASA's Curiosity, which was launched in 2011 and is tracking the Martian surface as we speak. The third organisation to get in on the act was the ESA (European Space Agency) who launched the Mars Express and Beagle 2 Lander in 2003. The Express has successfully orbited the planet but unfortunately communication was lost with Beagle 2 after its deployment. The most recent NASA craft is MAVEN, the Mars Atmospheric and Volatile EvolutioN, which launched in 2013 and will enter Martian orbit this September. Also in 2013, the Indian Space Research Organization (ISRO) launched its Mars Orbiter Mission (MOM) in its bid to become the fourth space agency to reach the red planet.

"If [meteorites] are large enough, they can strike with a great deal of force, forming huge craters"

Meteorites: the real shooting stars

Understanding the space rocks that survive the fall to Earth

Earth-bound space rocks have gone down in history as terrifying missiles that will wipe us all out, according to countless disaster movies, but what exactly are these great falling balls of fire?

Essentially, chunks of rock that have been chipped off from asteroids after collisions with obstructions in space – whether that be another asteroid, spacecraft or satellite – are called meteoroids. Occasionally, they can even be from the Moon or Mars, both of which can be identified as they are much younger than asteroid meteoroids.

It's all relative, though, as these 'young' meteoroids can still be an incredible 2.5 billion years old. They continue spinning through space until they are pulled into the gravitational field of a planet, like Earth. As they travel through the Earth's atmosphere in a dazzling streak of light across the sky, they are called meteors or shooting stars.

Any that make it all the way through the atmosphere and down to Earth's surface are called meteorites. If these are large enough, they can strike with a great deal of force, forming huge craters. These vast cavities are still providing scientists with data, such as when they landed and the impact they had on the Earth when they did.

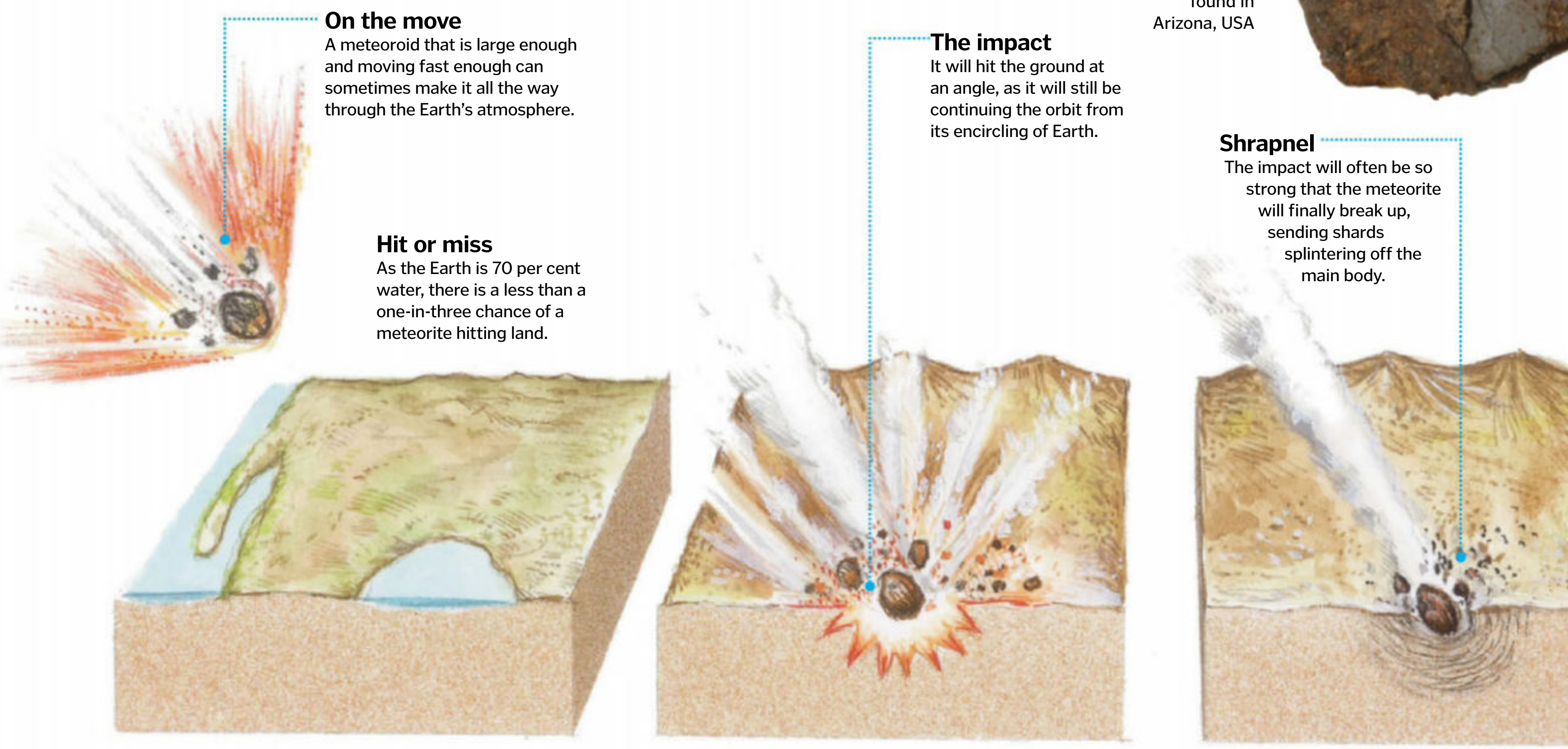
The most famous of all space rock strikes would have to be the one that wiped out the dinosaurs. When a ten-kilometre (6.2-mile) wide asteroid crashed into Mexico 66 million years ago, it triggered volcanic eruptions, tsunamis and mammoth earthquakes that threw dust into the atmosphere and blocked out the sunlight. A planet-wide freeze followed, sending temperatures plummeting and decimating plant and animal life.

Fortunately, institutions like NASA have early warning systems that can track meteorites for years before there is even the faintest chance of one colliding with Earth, so we should be safe from a real-life *Armageddon*.

A meteorite found in Arizona, USA

When meteorites attack

What happens when a meteoroid is large enough to survive the journey through the atmosphere?



1. BIG

Sudbury crater
This 130km (81mi)-wide crater in Ontario, Canada was formed 1.85bn years ago, with shards thrown 800km (500mi) away.

2. BIGGER

Vredefort crater
The oldest known meteorite crater in the world, this vast crater measures 190km (118mi) across South Africa.

3. BIGGEST

Chicxulub crater
Thought to be created by the impact that wiped out the dinosaurs, this crater in Mexico could be up to 300km (186mi) wide.

DID YOU KNOW? Meteoroids can travel at up to 72km (45mi) per second as they enter Earth's atmosphere

Meteor explosion over Russia caught on film

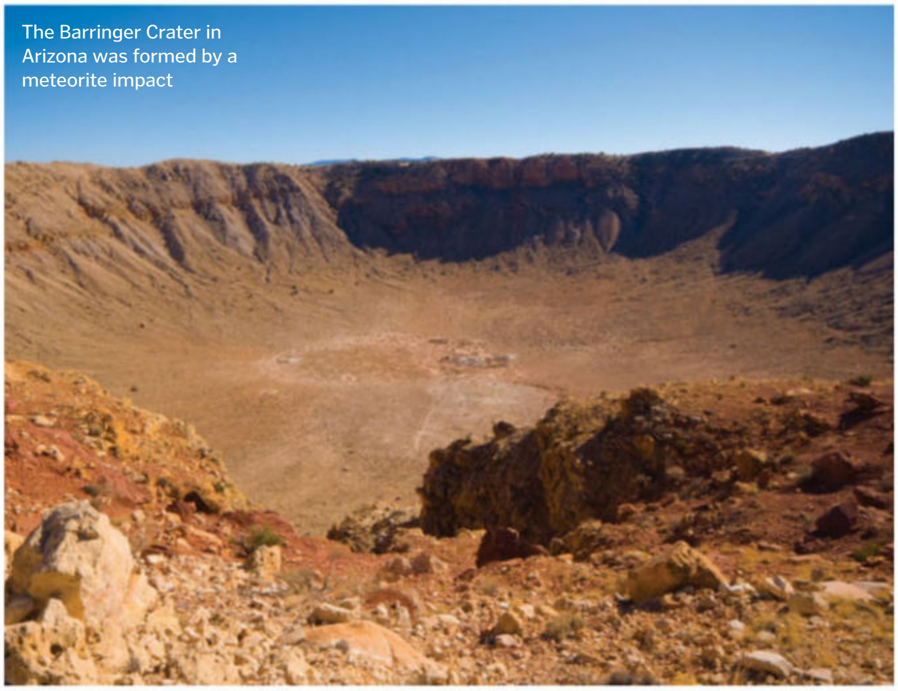
Fireball causes skin and retinal burns

In February 2013, the citizens of Chelyabinsk in Russia had a close shave with disaster when a 17-metre (56-foot) long meteor broke up over their city.

The space rock weighed an amazing 10,000 tons and tore through the sky, injuring over 1,000 people, despite not actually coming into contact with anything until it broke through the ice on top of Lake Chebarkul.

Injuries sustained included skin and retinal burns from the intense heat and light, as well as being hit by glass and debris blown out from the blast, which was the equivalent of 500 kilotons of TNT exploding. Although it fortunately landed in water, the fact that it caused so much destruction without even touching land shows the incredible power these asteroid offshoots can cause.

A quick internet search will bring up several must-see videos of the meteor and the effects it had.

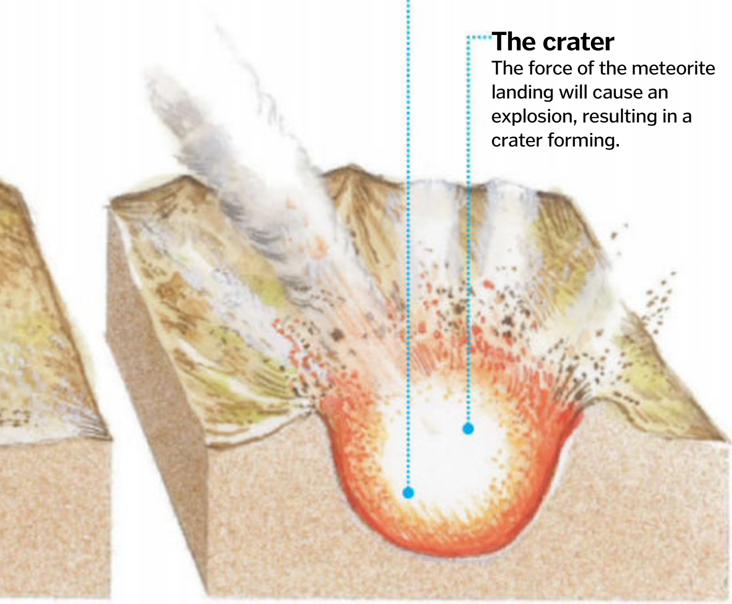


The Barringer Crater in Arizona was formed by a meteorite impact

Shooting stars

A shooting star is one of the most incredible things you can see in the night sky and a shower of them is required viewing for all budding astronomers. What you're seeing is not actually a star at all, however, but in fact the final moments of a meteor that has entered Earth's atmosphere and is burning up in the super-hot environment.

Around 100 tons of material enter Earth's atmosphere every day, but most of it is much too small to see from the surface. Hence a meteor shower is a once-a-year event, only occurring when the Earth passes through an area of space particularly heavy with meteors, resulting in a sky full of dazzling shooting stars.

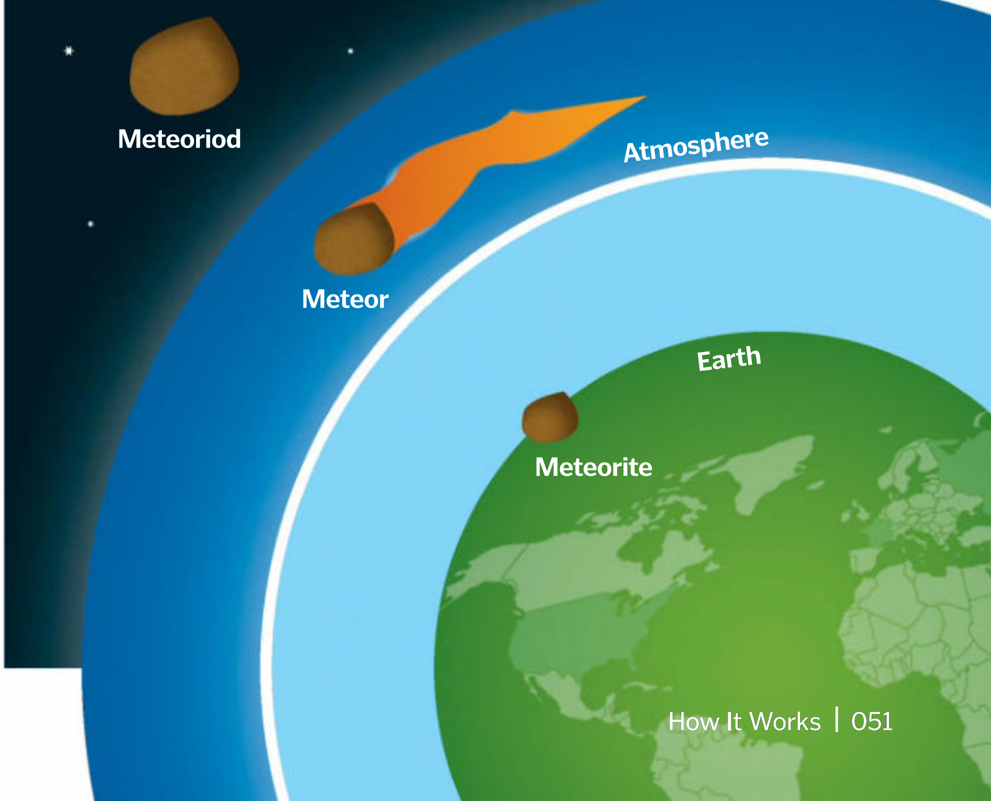


Going down
The high-energy impact creates heat and pressure that melts some of the surrounding rock.

The crater
The force of the meteorite landing will cause an explosion, resulting in a crater forming.

Meteor or meteorite

The difference in what we call space rocks lies in where they are – here's a simple guide



Waterfall wonders

The story behind the world's greatest waterfalls

Big waterfalls are among the most spectacular and energetic geological features on Earth. The thundering waters of Niagara Falls can fill an Olympic-sized pool every second. Visitors are drenched with spray and deafened by volumes reaching 100 decibels, equivalent to a rock concert.

A waterfall is simply a river or stream flowing down a cliff or rock steps. They commonly form when rivers flow downhill from hard to softer bedrock. The weak rock erodes faster, steepening the slope until a waterfall forms. The Iguazú Falls on the Argentina-Brazil border, for example, tumble over three layers of old resistant lava onto soft sedimentary rocks.

Any process that increases the gradient can generate waterfalls. A 1999 earthquake in Taiwan thrust up rock slabs along a fault, creating sharp drops along several rivers. A series of new waterfalls appeared in minutes, some up to seven metres (23 feet) high – taller than a double-decker bus.

Many waterfalls were created by rivers of ice during past ice ages. These glaciers deepened big valleys, such as Milford Sound in New Zealand. The ice melted and shallow tributaries were left 'hanging' high above the main valley. Today the Bowen River joins Milford Sound at a waterfall 162 metres (531 feet) high, almost as tall as the Gherkin skyscraper in London.

Waterfalls vary enormously in appearance. Some are frail ribbons of liquid while others are roaring torrents. All waterfalls are classed as cascades or cataracts. Cascades flow down irregular steps in the bedrock, while cataracts are more powerful and accompanied by rapids.

Gigantic waterfalls seem ageless, but they last only a few thousands of years – a blink in geological time. Debris carried by the Iguazú River is slowly eroding the soft sediments at the base of the falls, causing the lava above to fracture and collapse. Erosion has caused the falls to retreat 28 kilometres (17 miles) upstream, leaving a gorge behind.

The erosional forces that birth waterfalls eventually destroy them. In around 50,000 years, there will be no Niagara Falls to visit. The Niagara River will have cut 32 kilometres (20 miles) back to its source at Lake Erie in North America and disappeared.

The sheer force and power of waterfalls makes them impossible to ignore. Daredevils across the centuries have used them for stunts. The first tightrope walker crossed the Niagara Falls in 1859. Risk-takers have ridden the falls on jet skis, in huge rubber balls or wooden barrels and many have died. The steep drops

HEAD 2 HEAD
THE BIGGER THE FALL...

1. TALLEST

Angel Falls
The world's highest waterfall drops 979m (3,212ft) from a flat plateau in Venezuela, barely making contact with the underlying rock.

2. WIDEST

Khone Falls
These waterfalls in Laos are about 10.8km (6.7mi) across. They also have a very high average flow rate of over 10,000m^3/s (353,147ft^3/s).

3. LARGEST

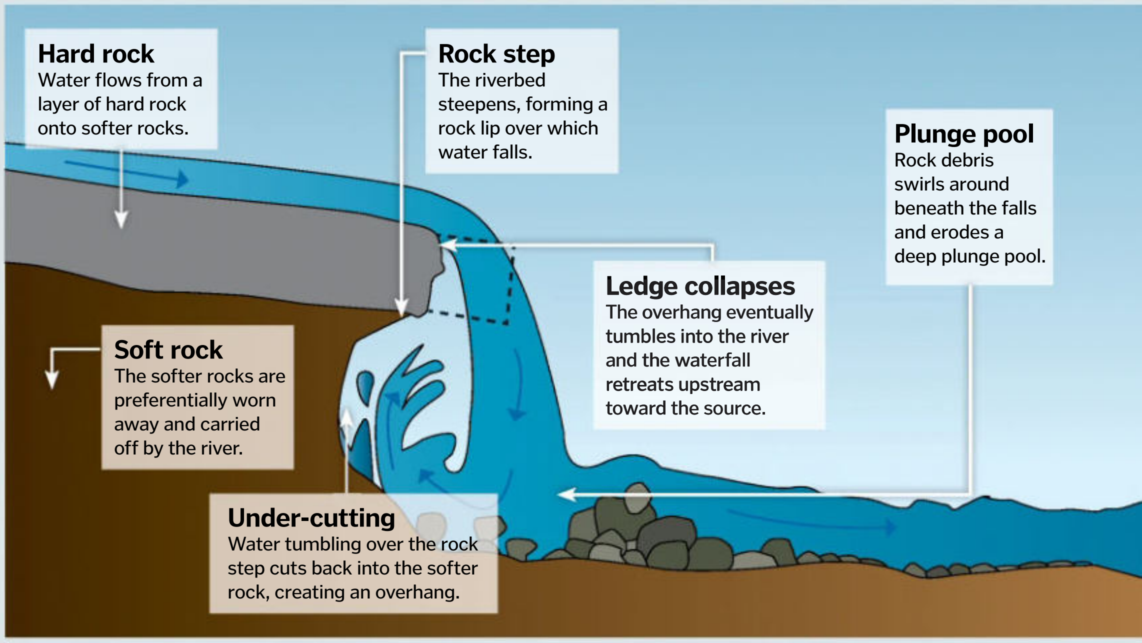
Victoria Falls
Known as the 'smoke that thunders', Victoria Falls spans the African Zambezi River and produces the largest sheet of falling water.

DID YOU KNOW? *Fictional detective Sherlock Holmes fell into the Reichenbach Falls while fighting his nemesis Professor Moriarty*

Erosion power

Waterfalls appear to be permanent landscape features, but they are constantly changing thanks to the geological process of erosion. Erosion is the gradual wearing down of rock. Rivers transport sand, pebbles and even boulders, which act like sandpaper to grind down rock.

Waterfalls often form when rivers flow from hard to softer rocks. Over thousands of years, the softer rocks erode and the riverbed steepens. The river accelerates down the steep slope, which increases its erosive power. Eventually the slope is near vertical and the river begins cutting backward. As sections of the overhang collapse, the waterfall gradually moves upstream toward the river's source.



What is the biggest waterfall on Earth?

This is a tricky question as there is no standard way to judge waterfall size. Some use height or width, but the tallest one, Angel Falls, is only a few metres across at its ledge so is nowhere near the widest. Others group waterfalls into ten categories based on volume flowing over the drop.

Every method has problems. Boyoma Falls in the Congo is one of the biggest waterfall on Earth by volume, but some argue the turbulent waters are simply river rapids. Shape is a popular and easy-to-digest, but unscientific, way to classify waterfalls, as many of them fall (literally) into several different categories.

Horsetail
In horsetail waterfalls, the water stays in constant contact with the underlying rock, as it plunges over a near-vertical slope. One example is the famous Reichenbach Falls in Switzerland.

Block
A wide river tumbles over a cliff edge, forming a rectangular 'block' waterfall that is often wider than it is high. Famous examples include Victoria Falls in Africa and the Niagara Falls in North America.

Punchbowl
A river shoots through a narrow gap and cascades into a deep plunge pool. The name 'punchbowl' refers to the shape of the pool. An example of a punchbowl fall is Wailua Falls, Hawaii.

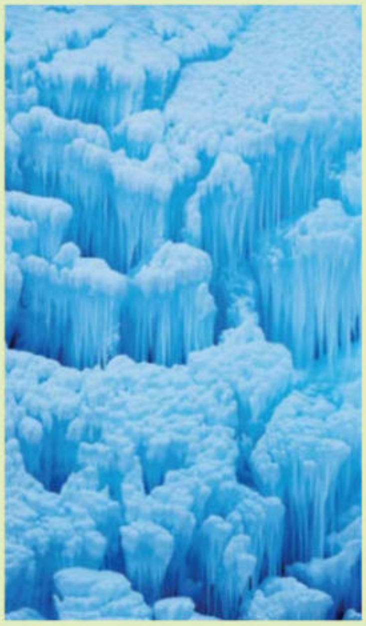
Plunge
Water spills straight over a ledge while barely touching the rock beneath. Angel Falls in Venezuela, the world's highest uninterrupted waterfall, is a member of this category.

Tiered
The waterfall has several drops, each with their own plunge pool. One example is Gullfoss, Iceland. Some tiered waterfalls, such as the Giant Staircase, USA, resemble several separate falls.

Chute
These resemble extreme rapids more than waterfalls. A pressurised frothy mass of water is forced through a suddenly narrower channel. An example is Barnafoss, a waterfall in Iceland.

Frozen waterfalls

Ice climbers in Colorado every winter tackle a frozen waterfall called the Fang – a free-standing icicle over 30m (100ft) tall and several metres wide. The idea of a frozen waterfall may seem strange. Rivers are slow to cool because their moving waters constantly mix and redistribute heat. When temperatures drop below freezing, water cools and ice crystals called frazil form. Only a few millimetres across, these start the freezing process by gluing together. Ice sticks to the bedrock or forms icicles on the rock lip. After a lengthy cold spell, the entire waterfall will freeze.



"Above Niagara Falls, treaties have balanced energy generation with iconic scenery since 1909"

mean waterfalls often pose a navigation problem. In the 19th century, the Welland Canal was built to bypass Niagara Falls.

People have long dreamed of harnessing the power and energy of the biggest falls. The first recorded attempt to use the swift waters above Niagara, for example, was in 1759 to power a water wheel and sawmill. Today many hydroelectric plants generate electricity near big waterfalls, such as the Sir Adam Beck Power Plants above Niagara Falls. River water is diverted downhill past propeller-like turbines. The rushing flow spins the turbine blades, creating renewable electricity. The bigger the drop, the faster the water, and the more energy it contains as a result.

Harnessing rivers for electricity can conflict with the natural beauty of their waterfalls. The Guaíra Falls on the Paraná River, probably the biggest waterfall by volume, were submerged in the 1980s by the building of the Itaipu hydroelectric dam.

These days, the conflict between power and nature is greater than ever. Dr Ryan Yonk is a professor of political science at Southern Utah University. According to him, "the demand for electricity generation in the developing world is not going away and it's going to ramp up."

Controversial hydroelectricity projects, like some in Asia, involve a trade-off between beauty and tackling climate change. Dr Yonk believes "the alternatives in those countries are likely to be very dirty coal."

Above Niagara Falls, treaties have balanced energy generation with iconic scenery since 1909. During the summer, when most of the 12 million annual tourists visit, about half the water carried by the river must flow over the falls – an incredible 2,832 cubic metres per second (100,000 cubic feet per second).

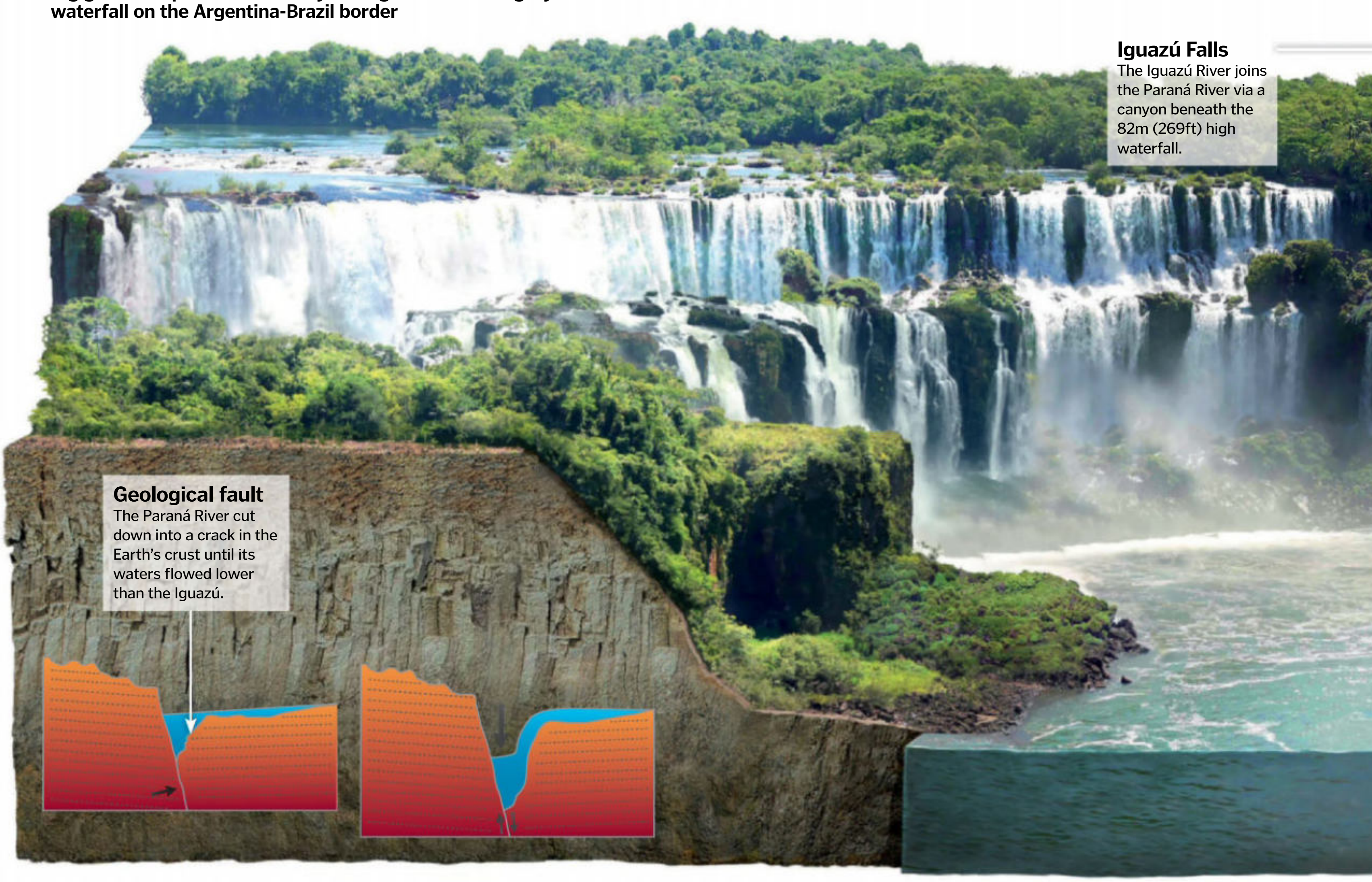
Yet these summer flow limits have a price. One study says the loss of potential electricity from the current treaty is 3.23 million megawatt hours each year – enough to run four million light bulbs.

Withdrawing more water could have benefits above hydropower generation. Samiha Tahseen is a civil engineering PhD student, studying Niagara flow at the University of Toronto. According to her, "you can reduce the erosion of the falls."

Another advantage to limiting flow in waterfalls is minimising the problem of mist obstructing the view. Samiha adds: "There is no denying that the mist is dependent on the flow so if you decrease the flow of the falls a little bit, that helps."

The birth of Iguazú Falls

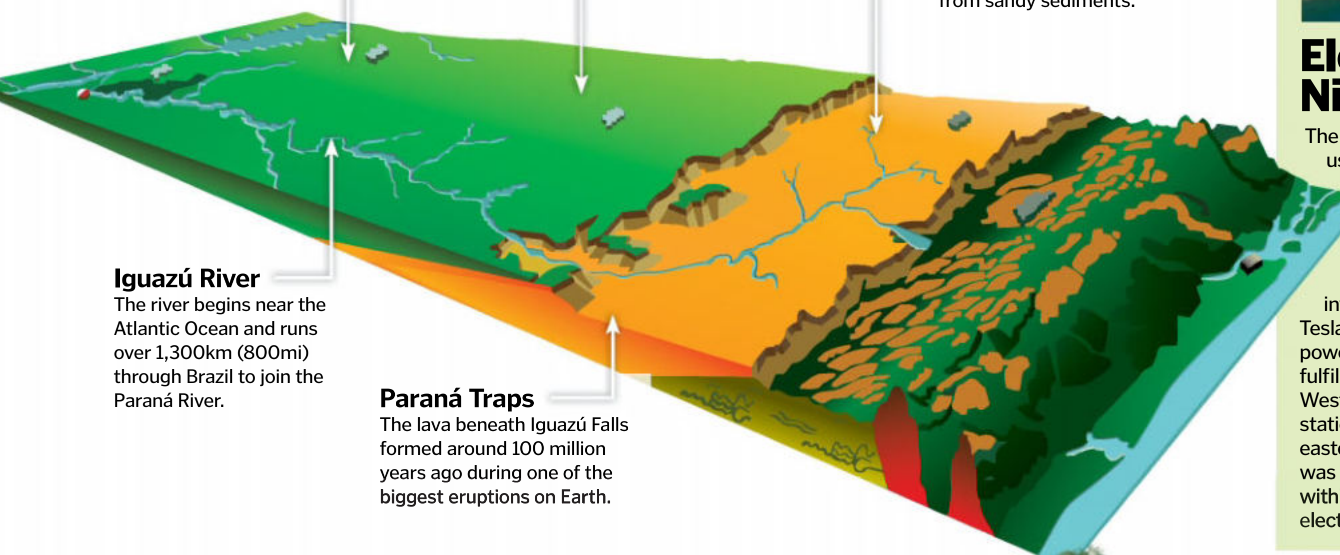
A gigantic eruption millions of years ago created a mighty waterfall on the Argentina-Brazil border



THE STATS
IGUAZÚ FALLS

NUMBER OF DROPS	275
TOTAL HEIGHT	82m
WIDTH	2.7km
FLOW RATE	$1{,}756m^3/s$
MAX FLOW	$12{,}750m^3/s$

DID YOU KNOW? *The first person to go over Niagara Falls in a barrel was a 63-year-old teacher in 1901 – she survived*



Paraná River
The second-longest river in South America, after the Amazon.

Volcanic rock
A gigantic eruption covered the Iguazú area with layers of lava up to 1km (0.6mi) thick.

Sedimentary rocks
Beneath the layers of lava are softer, older rocks made from sandy sediments.

Iguazú River
The river begins near the Atlantic Ocean and runs over 1,300km (800mi) through Brazil to join the Paraná River.

Paraná Traps
The lava beneath Iguazú Falls formed around 100 million years ago during one of the biggest eruptions on Earth.

Electrifying Niagara Falls

The first large power station to use alternating current was built at Niagara Falls in 1895. It was the first big supplier of AC, the form of electricity that supplies businesses and homes today, invented by genius Nikola Tesla. Tesla imagined harnessing the power of the falls. His dream was fulfilled when industrialist George Westinghouse built a Niagara station big enough to supply the eastern United States. The plant was the largest of its age and, within a few years, its power lines electrified New York City.

Step-like waterfall
Iguazú Falls tumble over three successive lava flows, giving them a staircase shape with several cascades.

ON THE MAP

Where in the world
1 Niagara
2 Victoria
3 Iguazú
4 Angel
5 Reichenbach
6 Boyoma

> "Scales can distinguish whether a snake is venomous or not and what their habitat is like"

Snake skin

Why are serpents covered in scales?

Scales are absolutely essential to a snake. As well as protecting its body, they also provide a natural camouflage. Most importantly, a snake could not move without them. The scales are made out of out keratin, the same material that makes up human skin, hair and nails. This is what makes scales hard and shiny, although they are dry to the touch. Lacking eyelids, serpents instead have a transparent scale called a brille, which covers each eye. German for 'glasses', the brille does exactly that; acts as a protective lens in front of a snake's eye.

Scales can distinguish whether a snake is venomous or not and what their habitat is like. Every species has a unique pattern and each scale has a different function. Sea snakes have scales that are unsuitable for land as they are very grainy and loose. On the other hand, desert snakes have very rough skin used to grip sand, while the burrowing snake's smooth scales allow for rapid tunnelling. They even help the flying snake (chrysopelea) glide in the air by creating a hinged shape to act as a sort of natural parachute.

Snake skin has three layers. The top or outer layer is strictly skin while the two levels below are the scales. When the top layer of skin is too worn or parasite ridden, snakes go through ecdysis and shed their skin in favour of a new and undamaged coat.

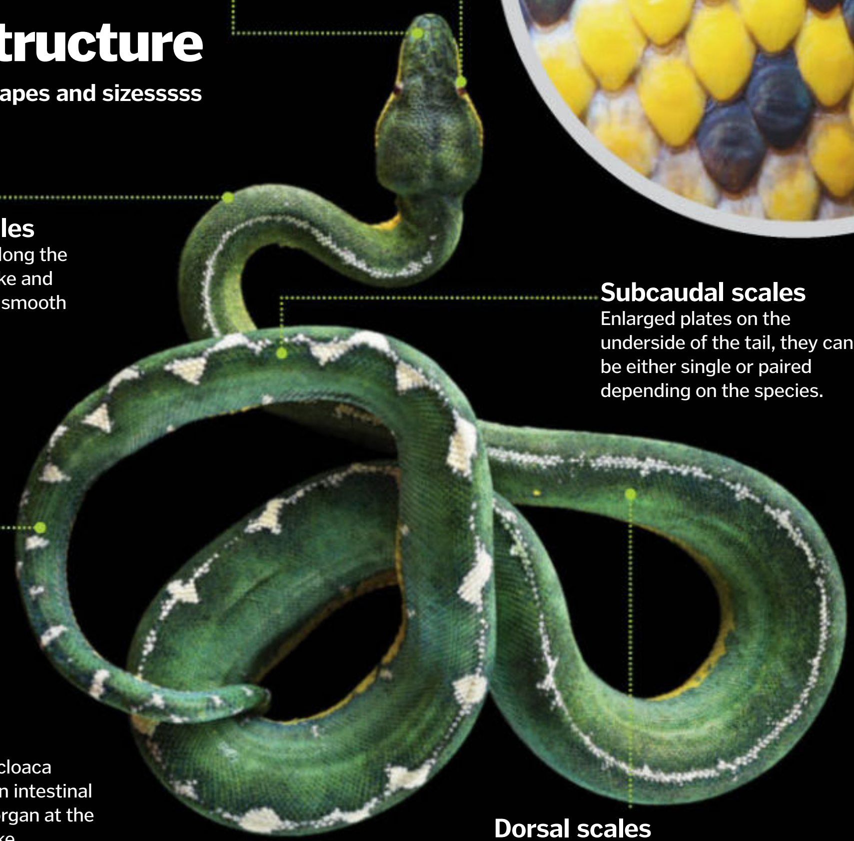
Scales throughout the animal kingdom

How does a snake's skin differ from others?

There are a number of key differences between the scales of snakes and fish. Snake scales are keeled and dry to allow them to slither across land, while a fish's are slimy to adapt to a life permanently in the sea. As well as being tougher, a snake's scales actually constitute their skin rather than being attached to the skin like on a fish. Snake scales are a single layer rather than separate pieces and get larger as the body grows. A fish will grow more scales rather that extend the ones they currently have. Legless lizards don't have large belly scales, which is one of the primary ways to tell them apart from snakes.

Skin structure

Scales of all shapes and sizesssss



Nasal scales
Divided into sub-sections, the scales protect and enclose the snake's nose.

Brille
These act as protective cover over the eye and are also called spectacles. They give a snake its intimidating stare.

Ventral scales
These extend along the belly of the snake and are particularly smooth for low friction

Subcaudal scales
Enlarged plates on the underside of the tail, they can be either single or paired depending on the species.

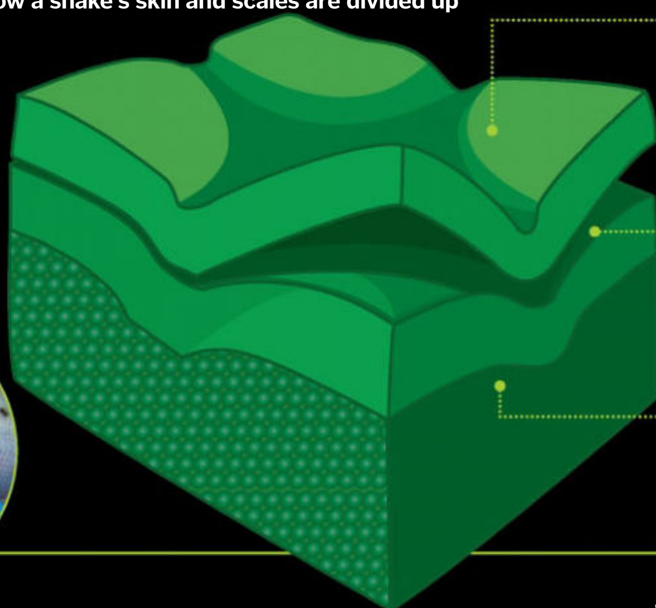
Anal scales
These protect the cloaca opening which is an intestinal and reproductive organ at the lower end of a snake.

Dorsal scales
Found all over the snake, these scales encircle the whole body except for the ventral scales.

Snake skin is a lot rougher than human skin, for a good reason

Layers of scales

How a snake's skin and scales are divided up



Outer layer
This layer of skin is shed when the snake moults and goes through ecdysis. A new layer replaces it.

Middle layer
The new outer layer comes from the middle section, which is a series of scales and is never shed.

Inner layer
The inner level contains the skin colour. The outer layer is skin but the middle and inner are scales.


CLOSER THAN YOU'D THINK
AS SEEN ON BBC AND CHANNEL 4
IT'S WELL KNOWN THAT ORANGUTANS SHARE
97.6% OF THEIR DNA WITH HUMANS.
SEE HOW THE DURRELL TEAM DISCOVERED HOW CLOSE WE REALLY ARE...
WWW.DURRELL.ORG/CLOSER
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saving species from extinction

"Dogs can exhale through a couple of small slits in their noses, so any smell stays in their noses for a long time"

Dogs' incredible sense of smell

How canines can sniff out anything from criminals to cancer

A human nose might be able to detect more than one trillion smells, but it's no match for a dog's. Canines can sniff out explosives, drugs and even follow trails that are more than a week old.

They are able to do this due to the unique way their noses are set up. Humans have a single hole that takes in both air and smells, dogs have a flap of tissue that sends smells one way and air the other, allowing them to process the smells much more efficiently. They even have a system for the other direction, so while humans breathe out through their single nose hole and blow out any smells, dogs can exhale through a couple of small slits in their noses, meaning that any smell stays in their noses for a long time, allowing them to track scents for up to 210 kilometres (130 miles).

Canines' advantage over humans extends right down to cellular level as well. They have about 230 million olfactory cells, the ones used for smelling, in their nose. By way of comparison, humans have to make do with anything between five and 40 million. No wonder they are always around as soon as you're opening the dog-food tin!

However, dogs don't just have this sense in order to sniff out their next meal. Their noses are pretty much equivalent to our eyes in terms of reading the world around them. When dogs inhale, they aren't just picking up on scents. Their vomeronasal organ is at the bottom of their nasal passage and enables them to detect pheromones – chemicals that can reveal stacks of information about the other animals that have been in that area before them.

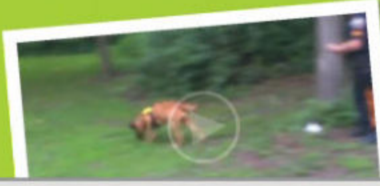
Their excellent noses make dogs some of nature's best trackers

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

Amber the bloodhound tracks down a person

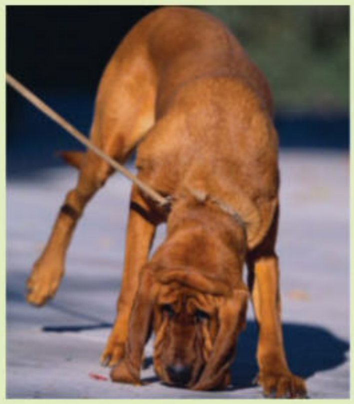
www.howitworksdaily.com



DID YOU KNOW? *Bloodhounds are known as St Hubert hounds – they were bred by the patron saint of hunters, Hubertus*

A bloodhound nose best

Of all the thousands of dog species, bloodhounds are the best set up for detecting a scent. Their nose is an amazing 1,000 times more perceptive than a human's, due to the fact that they can have as many as 300 million olfactory cells in their nose, up to 60 times as many as we do, which allows them to perform such mind-bending feats as being able to tell if a teaspoon of sugar has been added to 4 million litres (a million gallons) of water. They have been known to track a scent for over 210 kilometres (130 miles) and can even continue following a smell over water, so criminals can't escape by crossing a river. Bloodhounds can also be used to sniff out drugs being smuggled by being trained to recognise the scent and react to people and luggage that are giving off that distinctive smell. The advanced nature of a dog's smelling ability and the fact that they are reliable, obedient and social animals means they are perfectly equipped to be a walking, barking tracking device.



Can dogs smell cancer?

Dogs' keen sense of smell has been put to work in the military, law enforcement and medical fields, but the latter has seen exciting new developments. Researchers at Pine Street Foundation in California trained five pooches to smell breast and lung cancer on a patient's breath, and the results were 88 to 99 per cent accurate. Other tests have shown that dogs can detect prostate and bladder cancer in urine. It's thought that, after being trained to recognise the smell of hormones and pheromones in the urine of cancer patients, they are then able to sniff it out with great accuracy. They won't replace medical tests any time soon, but can certainly play a part.

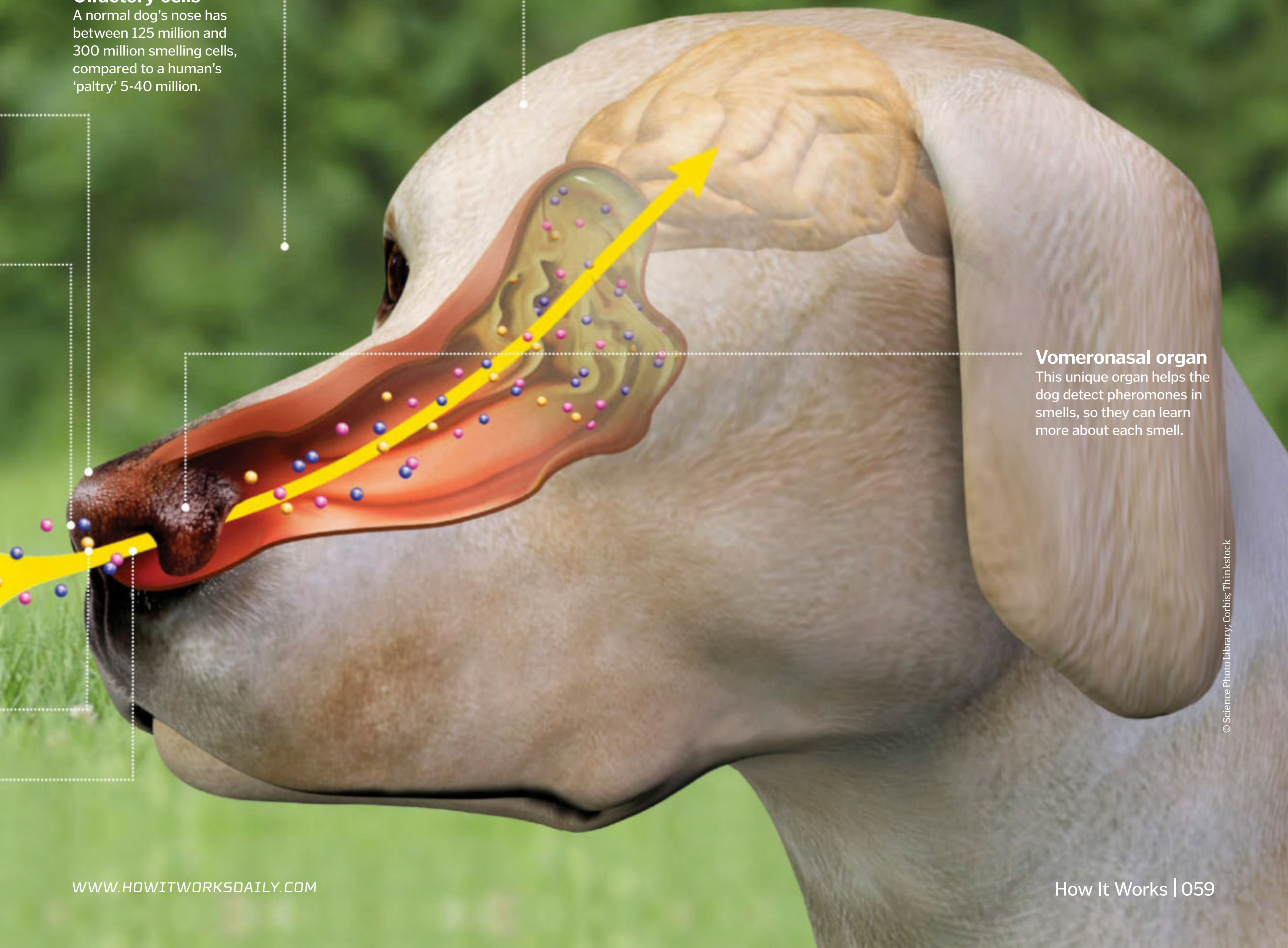
The science of sniffing

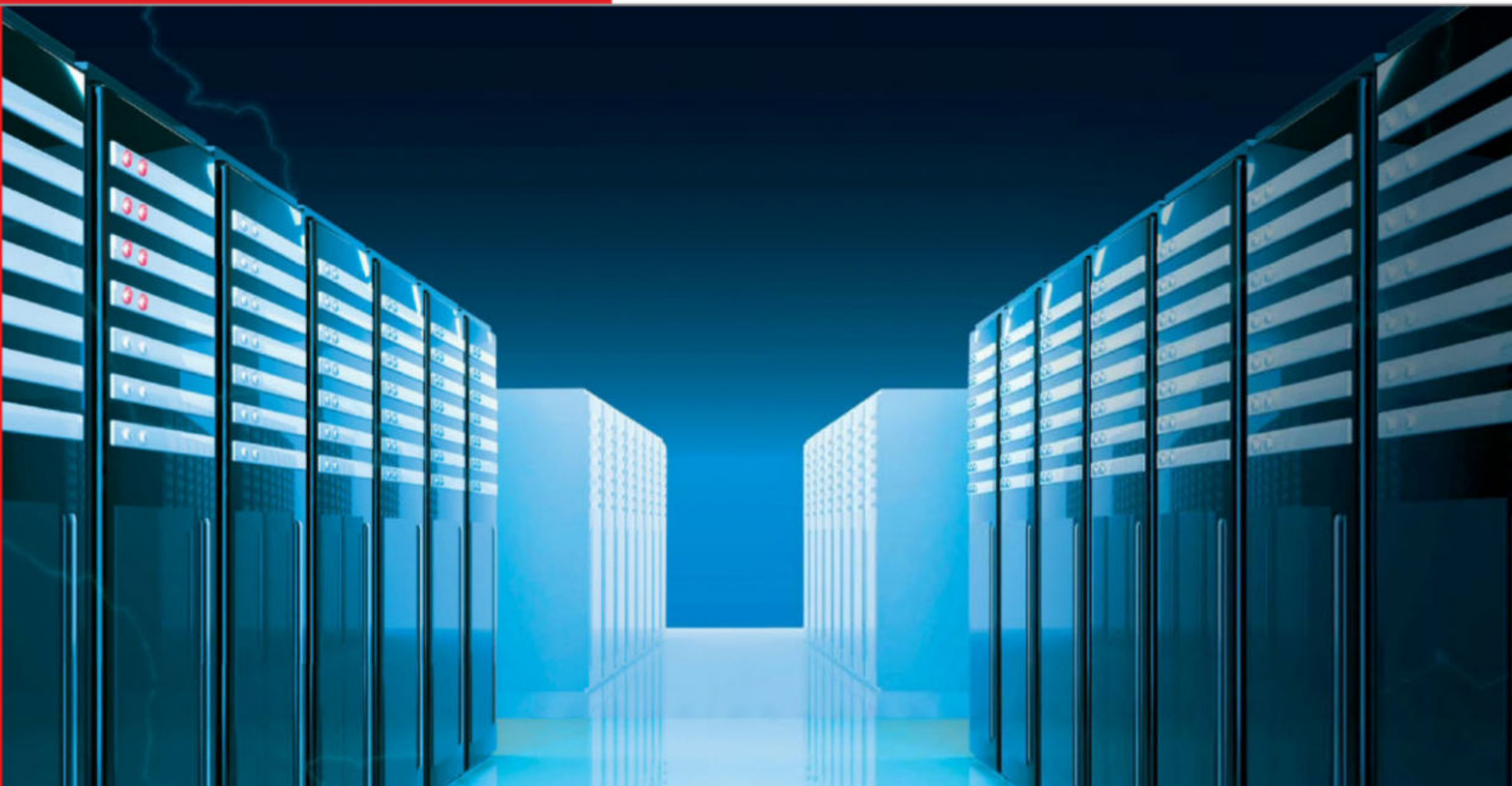
How a dog's sense of smell outperforms human noses

Olfactory cells
A normal dog's nose has between 125 million and 300 million smelling cells, compared to a human's 'paltry' 5-40 million.

Analysis
Once the turbinate recognises a smell, it sends the signal onward to the brain for analysis.

Vomeronasal organ
This unique organ helps the dog detect pheromones in smells, so they can learn more about each smell.





SUPER COMPUTERS

THE FASTEST & MOST POWERFUL COMPUTERS ON EARTH

• 15 YEARS OF CALCULATIONS IN ONE SECOND • 83,000 PROCESSORS • AS POWERFUL AS 715,000 iPADS

If you gave everyone in the UK a calculator and set them doing sums at the rate of one every second, it would take 15 years of combined, non-stop calculation to manage what the fastest supercomputer in the world can do in just one second. And yet the basic chips that power this mathematical monster are virtually the same as the CPU in your home PC.

The first supercomputers were built just as vacuum valve technology was beginning to be replaced with transistors. Manchester University installed one of the very first in 1962; a machine called Atlas. This computer had as much processing power as every other computer in the UK combined. In the USA, a company called CDC dominated the market for supercomputers for most of the 1960s. The CDC 6600 was ten times faster than its nearest competitor and the company sold 100 of them for $8 million each. The genius behind these computers was a man called Seymour Cray. When Cray left to form his own company in 1972, the supercomputer business jumped up a gear. The Cray-1 was the first to use integrated circuits (computer chips) instead of separate transistors. A lot of its speed came from a

5 TOP FACTS FASTEST COMPUTERS

Tianhe-2 – 33,863 Tflops

1 Tianhe means Milky Way. 1,300 scientists and engineers collaborated to build it. There are 3,120,000 computing cores altogether, occupying 720m² (7,750ft²) of floor space.

Titan – 17,590 Tflops

2 Housed in 200 cabinets, Titan uses 8.2MW of power - as much as 2,000 private households. The cooling fans are so loud that staff have to wear ear protection.

Sequoia – 17,173 Tflops

3 It has modelled the electrical activity of the human heart and simulated 3.6 trillion stars in the cosmos. Sequoia was the first computer to use a million cores at once.

K Comp – 10,510 Tflops

4 Named after the Japanese word 'kei' which means ten quadrillion, in 2011 the K Computer became the first in the world to exceed 10,000 Tflops in size.

Mira - 8,587 Tflops

5 Based at the Argonne National Laboratory, outside Chicago. In one day it can perform as many calculations as a desktop computer would manage in 20 years.

DID YOU KNOW? The USA is home to 233 of the top 500 supercomputers. China has 76, the UK has 30

technique known as vector processing. It exploits the fact that most supercomputer applications run the same few calculations over and over across a huge dataset stored in memory. Traditionally, computers would fetch the first datapoint from memory, perform all the calculations, write the result back to memory and then fetch the next datapoint and repeat the entire process. The Cray-1 treated the operation like a factory assembly line, continuously feeding in data at one end and writing it back out at the other end. This ensured all circuits were busy all the time, instead of spending a while waiting for the next piece of data. The Cray-1 was ultimately succeeded by the Cray-2 in 1985, which remained the fastest computer in the world until 1990.

Vector processing depends on your ability to move data rapidly through the processor and most of the performance of the Cray-2 was simply due to the much faster memory chips it used. In the 1990s, supercomputer designers tried a different tack. Instead of having just a handful of processors (the Cray-2 had just eight) sharing a common pool of memory, they gave each processor its own private memory and arranged large numbers of them in a grid. Called mesh computing, this system connected each processor to its four immediate neighbours using network technology. When processors want to exchange data, they send it as a network message. Although this is slower than wiring the processors directly together, they can operate more independently and don't need to communicate as often. This makes the system much more scalable – you can make your supercomputer faster simply by adding more processors to the mesh.

Since 1993, the world's fastest supercomputers have been ranked at **www.top500.org** using a benchmarking program that measures computer speed as the number of floating-point operations per second, or flops. Floating-point operations are essentially maths calculations that involve numbers with a decimal point. If you could work out the answer to a sum such as 12.83224 x 619.113 in one second, your brain would be running at a single flop. Modern supercomputers are measured in teraflops (Tflops) or thousands of billions of flops. The ten fastest computers on the Top500 list are all petaflops machines – a staggering thousands of teraflops in size. And they might be getting faster still. ▶

Q&A: Dr Alan Simpson, technical director

ARCHER's technical director reveals what the supercomputer's capable of

ARCHER is the most powerful supercomputer in the UK, currently ranked 25th in the world. It's hosted at Edinburgh University and we spoke to Dr Alan Simpson, who is the technical director of the Edinburgh Parallel Computing Centre.

What is the supercomputer ARCHER primarily used for?
ARCHER is used for materials and chemistry, engineering and environmental science. Example applications [for the supercomputer] include: longer-lasting smartphone batteries, quieter, [designing] more efficient aeroplanes and understanding climate change.

How does it compare to its predecessor?
ARCHER is capable of performing at least three times more computational research than its predecessor, HECToR.

Why does Edinburgh need its own supercomputer?
ARCHER is the national HPC [High Performance Computing] system for the United Kingdom and provides computational resources for nearly all the major UK research universities.

How many people have access to ARCHER?
ARCHER will have more than 3,000 users from more than 50 research institutions across the UK.

How many simulations are running on it at any one time?
Typically, more than 100 simulation jobs of varying sizes run at the same time, although some jobs take up the full system.

How much space does ARCHER take up?
ARCHER is made up of 16 cabinets, each of which is roughly the size of a wardrobe.

How much electricity does it use to run and to keep it cool?
It uses more than 1MW of electricity. ARCHER is housed in a specially designed building that minimises electricity used in overheads, particularly chilling. As Edinburgh has a cool climate for much of the year, we are able to exploit 'free cooling', ie passive cooling of water to the atmosphere.

What is your role within the ARCHER project?
I lead the teams providing science support and user support.

How long is it expected to last before it is replaced with something better?
The initial contracts for ARCHER are for four years. UK national HPC services typically last between four and eight years.

How many staff are required to run and maintain ARCHER?
There are two Cray engineers on site plus around five University of Edinburgh systems staff. There are also a significant number of staff involved in the service desk and in-depth computational science and engineering support.

What operating system does it use?
ARCHER uses Cray Linux Environment (CLE), a proprietary version of Linux.

IBM's Watson supercomputer beat human contestants to win $1m in the US game show *Jeopardy*

> *"In order to harness all the processors, you need to be able to break up your problem into smaller pieces"*

Modern supercomputers now use tens of thousands of processors. The only way to build them cost effectively is to use off-the-shelf components – most of the ten fastest supercomputers in the world use high-end variants of the Intel processors in your desktop PC. The newest ones use the graphics processing units (GPUs) found on your computer's graphics card too, but they don't use them for running video games. GPUs are very good at vector processing and by combining a CPU and a GPU into a single computing unit, hybrid supercomputers are able to gain the advantages of vector processing and mesh computing at the same time. GPUs now account for about 90 per cent of the processing performance of the fastest supercomputers and allow them to run ten times as fast as the previous generation, while only consuming about twice the power.

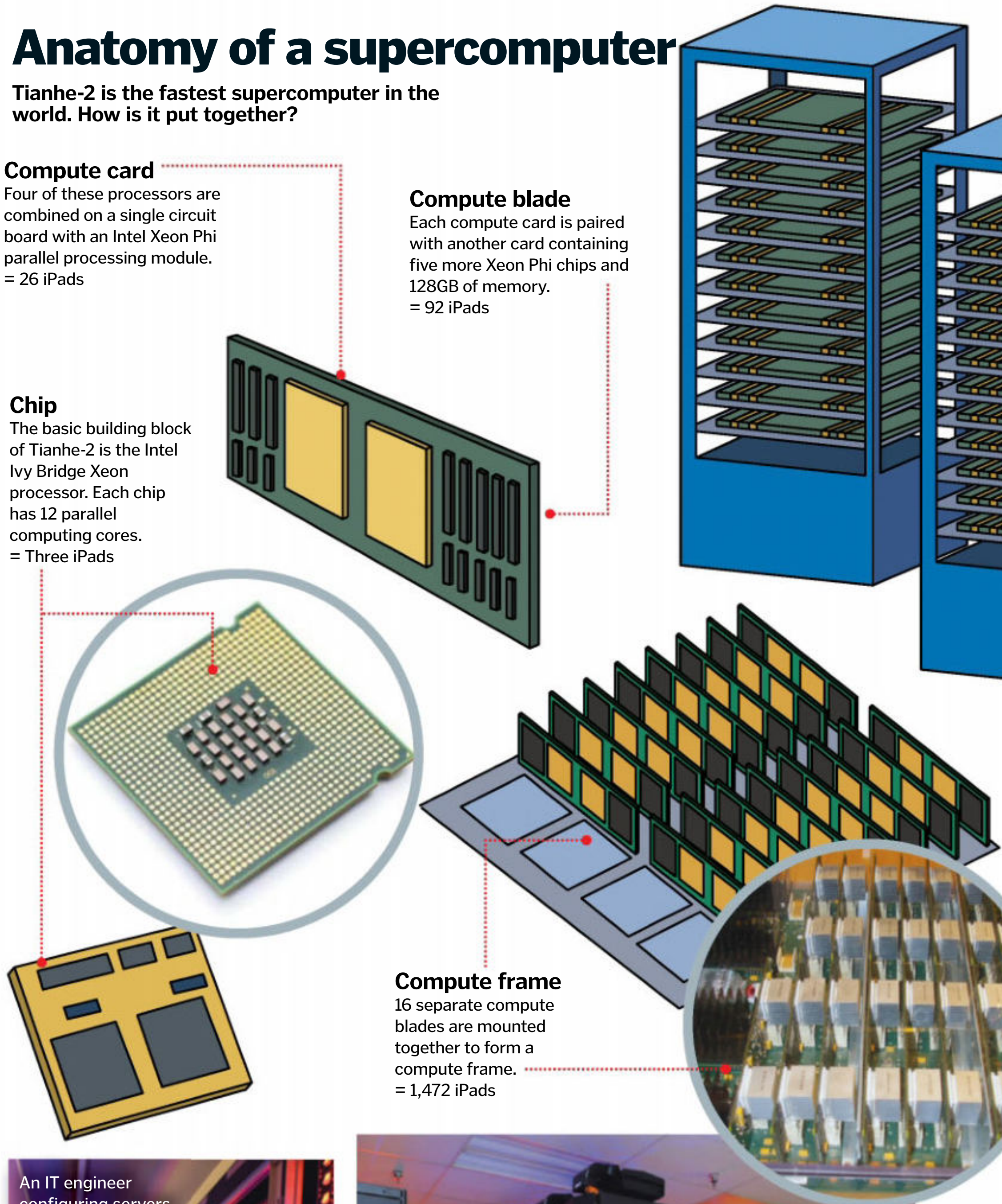
Supercomputer applications are written in the Fortran, C++ and Java programming languages, but programming massively parallel supercomputers is nothing like writing software for a Windows PC. In order to harness all the processors, you need to be able to break up your problem into smaller pieces that can be distributed among them.

If you are modelling the stars in the universe or the flow of air molecules over a turbine blade, you can't simply assign each processor to a different star or molecule because the calculations from one point in the simulation affect those around it.

The Global Address Space Programming Interface (GPI) is a new programming tool that allows each processor to treat all the memory on all the processors as a single shared pool. The GPI handles the work of sending the right messages to keep each processor up to date at all times, leaving the research scientist to get on with defining how the simulation should run, making the supercomputer more efficient. ►

Anatomy of a supercomputer

Tianhe-2 is the fastest supercomputer in the world. How is it put together?




An IT engineer configuring servers


NASA's Discover Supercomputer has almost 15,000 processors

Getting access

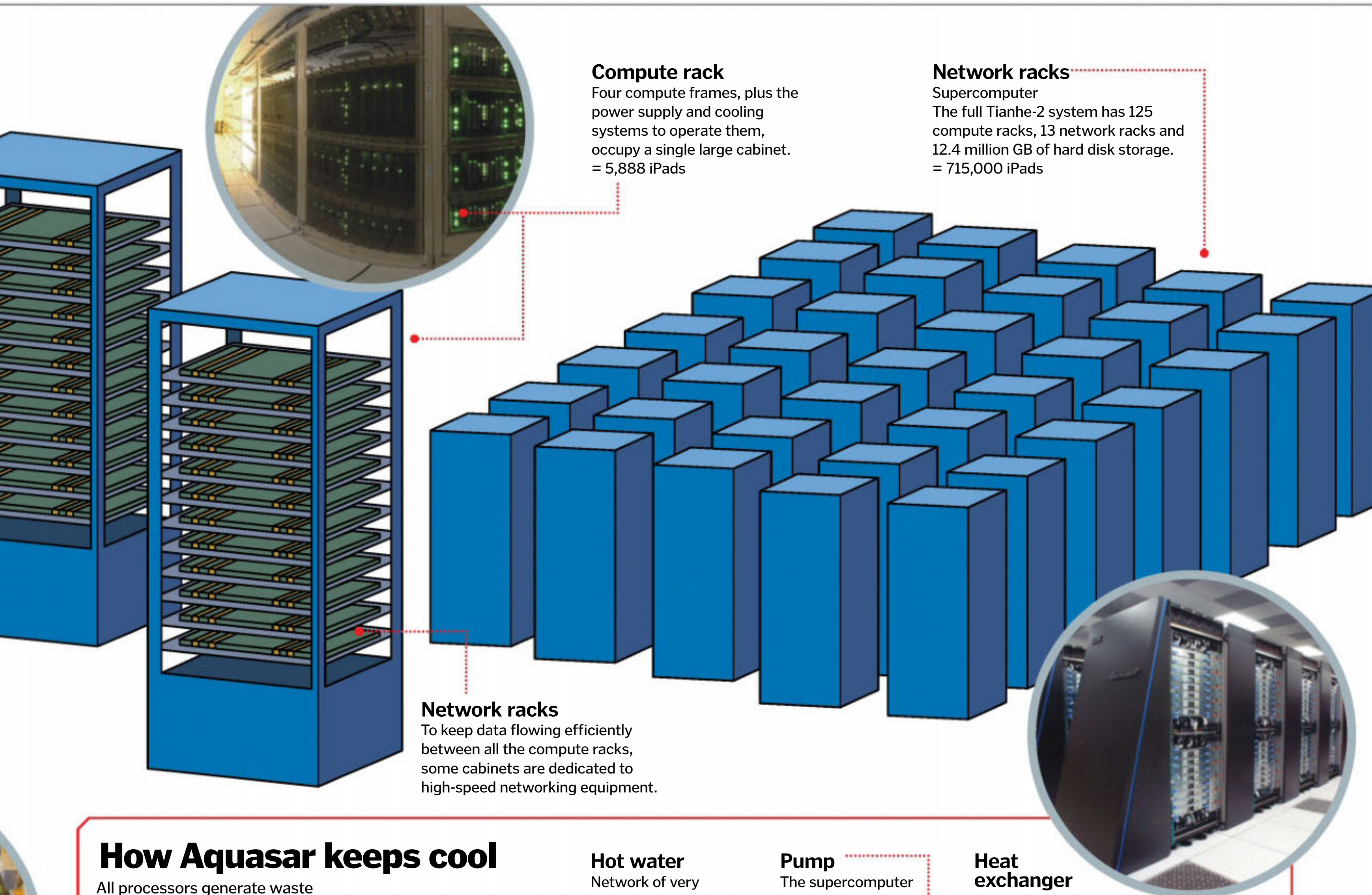
If you want to run your simulation on one of the really big supercomputers you'll need to write a proposal. Once a year, a vetting committee checks whether the science value is justified and the computer code is free of bugs. Your program should need at least 20 per cent of the total power of the supercomputer; otherwise it could just as well run on a smaller supercomputer. If you are a research scientist, access to the supercomputer is free, but you'll have to publish the results for everyone to use. Private companies pay for each processor they use and for each hour the simulation runs.

13 TRILLION

LARGEST SIMULATION

The largest fluid dynamics simulation ever used 13 trillion simulation 'cells' to model the behaviour of 15,000 bubbles on the Sequoia supercomputer at Lawrence Livermore National Laboratory in the USA.

DID YOU KNOW? *The #3 supercomputer in the world, Sequoia, uses as much power as 2 million laptops!*



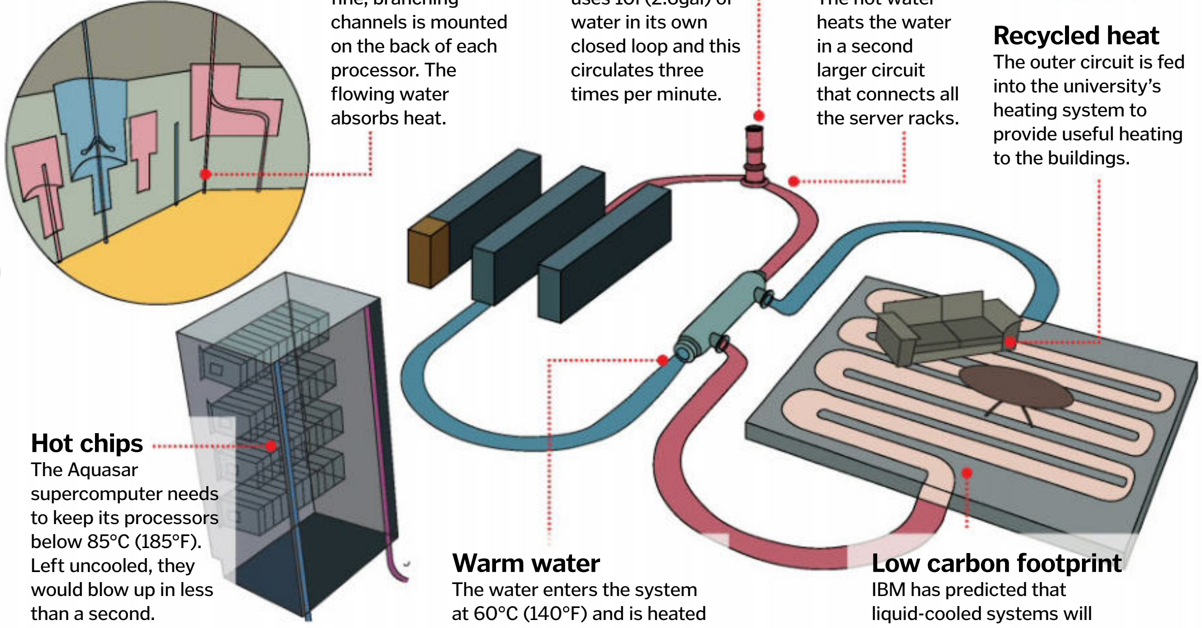
Compute rack
Four compute frames, plus the power supply and cooling systems to operate them, occupy a single large cabinet.
= 5,888 iPads

Network racks
Supercomputer
The full Tianhe-2 system has 125 compute racks, 13 network racks and 12.4 million GB of hard disk storage.
= 715,000 iPads

Network racks
To keep data flowing efficiently between all the compute racks, some cabinets are dedicated to high-speed networking equipment.

How Aquasar keeps cool

All processors generate waste heat. Left uncooled, the CPU in your desktop computer would get dangerously hot and could damage components. To prevent this, the heat is dissipated through radiator fins, which are cooled with a fan. But in a supercomputer, blowing air fast enough over all the processors in all of the cabinets can be tricky. Water cooling is more efficient because it takes a lot more energy to raise the temperature of water than air, but water is conductible so it has to be contained within leak-tight cooling pipes. The new SGI ICE X supercomputer sidesteps this by using a fluorine-based coolant called Novec, which was developed by 3M. This fluid conducts heat well but is electrically insulating, so it can be pumped directly over live circuit boards. Cooling this way uses just five per cent of the electricity of air cooling and takes up ten times less space than water cooling.



Hot water
Network of very fine, branching channels is mounted on the back of each processor. The flowing water absorbs heat.

Pump
The supercomputer uses 10l (2.6gal) of water in its own closed loop and this circulates three times per minute.

Heat exchanger
The hot water heats the water in a second larger circuit that connects all the server racks.

Recycled heat
The outer circuit is fed into the university's heating system to provide useful heating to the buildings.

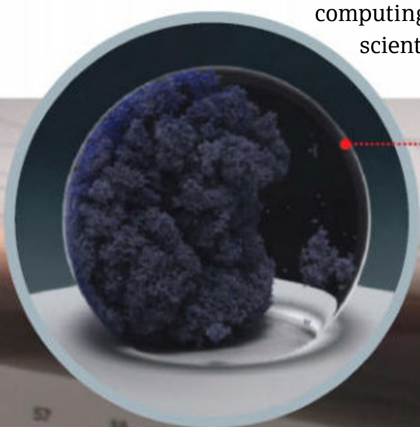
Hot chips
The Aquasar supercomputer needs to keep its processors below 85°C (185°F). Left uncooled, they would blow up in less than a second.

Warm water
The water enters the system at 60°C (140°F) and is heated to 65°C (149°F) while passing through the supercomputer.

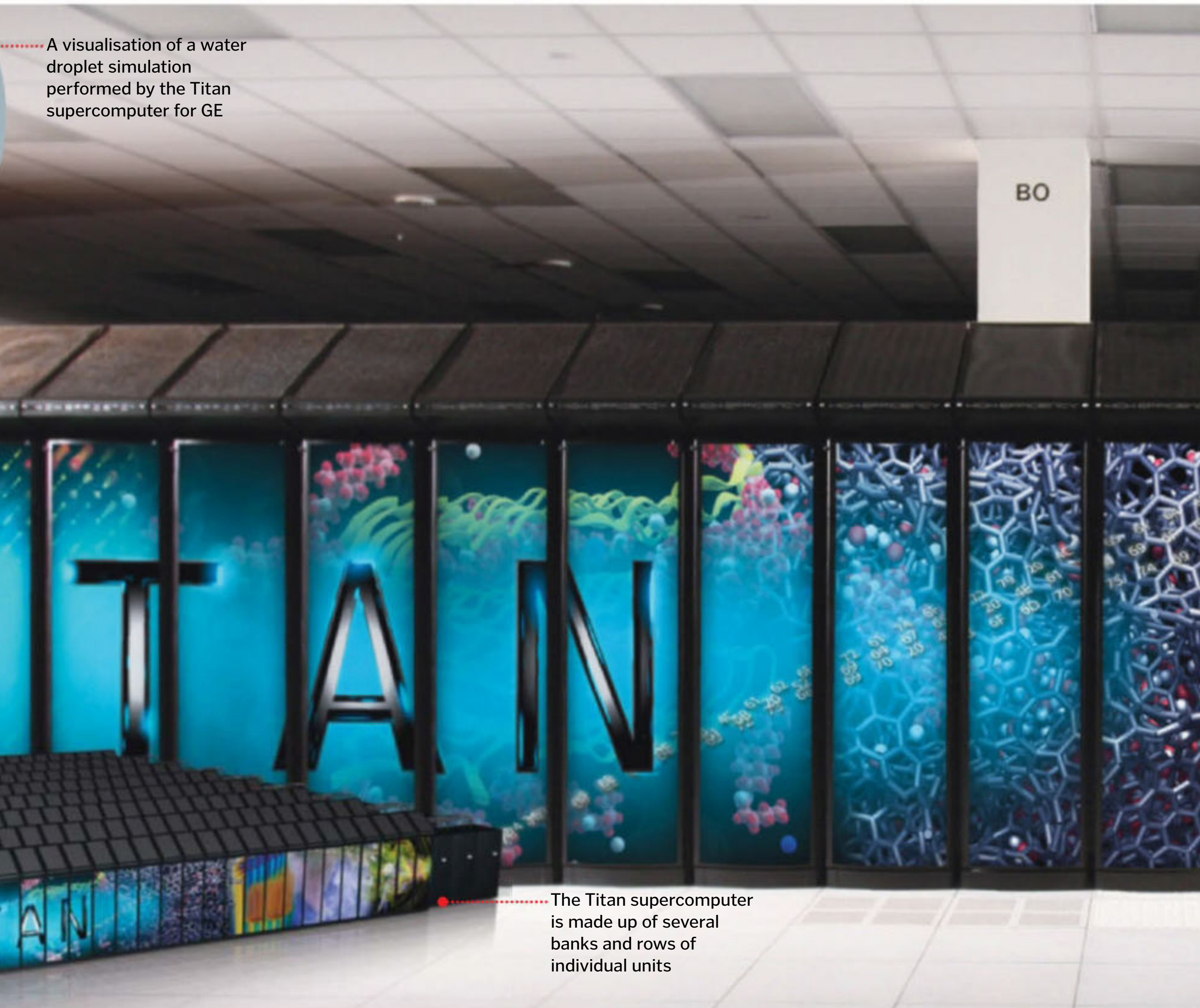
Low carbon footprint
IBM has predicted that liquid-cooled systems will lower the carbon footprint by 85 per cent.

> "Exaflops computing would allow scientists to finally model the human brain"

China, India and the USA are all committed to building an exaflops supercomputer by 2018. That's 1,000 petaflops, or about 30 times faster than the Chinese Tianhe-2 supercomputer, which is currently the world's fastest. Exaflops computing would allow scientists to finally model the human brain right down to a perfect simulation of each neuron, but the limiting factor right now isn't just money; it's electrical power. Tianhe-2 uses 24 megawatts of power. In the UK, the electricity bill for a machine this size would be over £21 million ($36 million) a year. Scaling this up to an exaflops supercomputer (1,000 petaflops) would require a large proportion of the output of a typical coal-fired power plant! However impressive the number-crunching abilities of supercomputers are, it seems they still can't match the energy efficiency of a brain. Maybe there's still a use for humans after all.



A visualisation of a water droplet simulation performed by the Titan supercomputer for GE



The Titan supercomputer is made up of several banks and rows of individual units

Nuclear energy

Denovo

Nuclear reactor technicians need to be able to able to predict the distribution of neutrons within the reactor core in order to make sure the nuclear fuel is burning uniformly.
Titan uses Denovo to simulate the complete state of a nuclear reactor core in just 13 hours. The data from this will allow the USA to extend the life of its ageing nuclear reactors, which currently supply approximately one-fifth of the country's electricity.

Molecular dynamics

LAMMPS

LAMMPS stands for Large-scale Atomic/Molecular Massively Parallel Simulator. An open-source program, it will run on an ordinary Windows PC. But it has been specifically optimised to scale well on the huge number of parallel processors in supercomputers. It uses Newton's equations of motion to model the forces between billions of atoms, molecules or larger particles at once. It's used for anything from nanotechnology to welding research.

Climate modelling

CAM-SE

CAM-SE models the atmosphere of the entire planet, divided into cells of 14km^2 (5mi^2)and with 26 vertical layers. It simulates the movement of wind, water vapour, carbon dioxide and ozone, including the chemical reactions that occur at different temperatures and altitudes. Titan can model more than two years of simulation time in a single day. This allows scientists to predict the effects of global warming, ozone depletion and refine long-term weather predictions.

KEY DATES
THE RISE OF THE SUPERCOMPUTER

1962
Atlas is installed at Manchester University. It was one of the first supercomputers.

1979
The Linpack benchmark is used to compare the speed of the most powerful supercomputers.

1985
The Cray-2 is built. It has more memory than every other Cray computer built to date combined.

1996
IBM's ASCI Red becomes the first to break the teraflops barrier and is the most reliable supercomputer ever built.

2011
IBM's Watson beats human contestants to win $1mn (£600,000) on US show *Jeopardy!*

DID YOU KNOW? Pangea owned by oil company Total, uses 120km (74.6mi) of fibre-optic cable to connect its processors

A technician working on upgrading Titan – a job that never stops

Combustion efficiency
S3D
S3D simulates the behaviour of burning hydrocarbons very precisely. This allows fuel injection systems for diesel and biofuel engines to be fine tuned so that they produce exactly the right pattern of fuel droplets to allow them to autoignite on each stroke of the engine's pistons. Jaguar was the first supercomputer to achieve a full simulation and Titan will continue this to even greater levels of precision. This will allow engineers to design more efficient engines.

Hard disks
WL-LSMS
Computer hard disks and electric motors rely on magnetic materials. The WL-LSMS gets its name from the two algorithms it uses to study the interactions between the electrons and atoms in these magnets: Locally Self-consistent Multiple Scattering and the Wang-Landau algorithm, named after the physicists that developed it. By combining both algorithms, the simulation can accurately represent the behaviour of magnetic materials down to the quantum level at temperatures just above absolute zero.

Radiation
NRDF
This application models the way that uncharged particles travel. The most important use for this is to simulate electromagnetic radiation in astrophysics, laser fusion and medical imaging. The NRDF application is also used as a testbed to develop new ways to program supercomputers, using algorithms that concentrate the processor power on the most important parts of the simulation and so allow it to model even larger and more complex systems.

ON THE MAP
Supercomputer spotting
1 Tianhe-2
2 Titan
3 Sequoia
4 K Computer
5 Piz Daint
6 ARCHER

11th century Aztecs build floating rafts on Lake Tenochtitlan for crops nourished from the lake below.

1699 John Woodward shows plants grow better in river water mixed with loam than in pure rainwater.

1938 Dennis Hoagland and Daniel Arnon publish *The Water Culture Method For Growing Plants Without Soil.*

1938 Hydroponic-grown vegetables feed Pan-Am Airways staff when refuelling on a Pacific island.

DID YOU KNOW? Aquaponics combines hydroponics with fish-farming, as plants clean up the waste water from fishfarm tanks

Growing plants without soil

Hydroponic systems already grow tomatoes and lettuce, and might one day produce new superfuels

Hydroponics is a system of growing crops in nutrient-enriched liquid baths rather than soil. Normally, roots anchor the plant in the ground and absorb all the water, minerals and nutrients from the soil the plant needs in order to grow. They cannot break down the soil particles but rely on the dissolved solution between them.

Hydroponics does away with soil and grows plants with their roots suspended in an aerated nutrient solution in greenhouses. The roots can also be supported in an inert medium, like gravel or sand, and flooded with a fertiliser solution. Tomatoes, cucumbers and peppers grown hydroponically in greenhouses in American deserts produce five to ten times as much crop weight per year as those grown in irrigated, open fields. Worldwide, hydroponic greenhouses now cover an area equivalent to 17,500 football fields and produce crops worth £3.5-4.7 billion ($6-8 billion) a year.

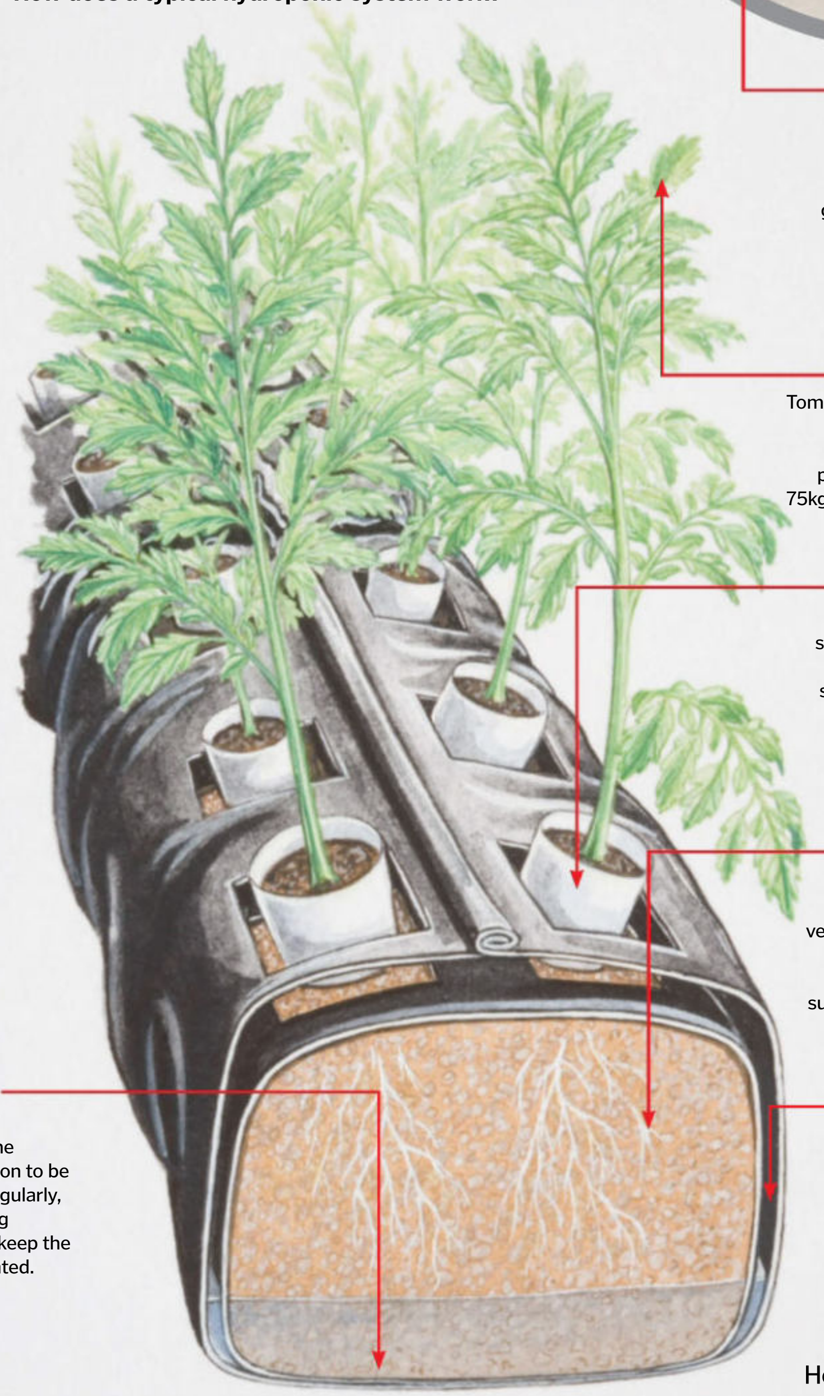
A new use is being developed for hydroponics. Algae (much simpler plants) are grown in tanks in the sunshine, absorbing CO_2 from the atmosphere as they grow. They develop 20 times as fast as traditional crops, so a portion can be harvested every day. This is fermented to produce ethanol and the mush left behind is buried. This process locks up carbon dioxide, helping to reduce greenhouse gases that cause climate change.

Growth spurt

- THE IDEAL CONDITIONS FOR GROWTH
- RAINWATER IS AN IDEAL SOURCE
- 25°C (77°F): OPTIMUM TEMPERATURE
- PLENTY OF OXYGEN IS NEEDED
- FRESH NUTRIENTS EVERY WEEK
- PH LEVELS SHOULD BE BETWEEN 5 AND 6

The greenhouse effect

How does a typical hydroponic system work?



The greenhouse environment
The sunlight that plants need for photosynthesis shines through the greenhouse glass, which also protects the plants from damaging winds.

Tomato plants
Tomatoes are especially well suited to hydroponic cultivation. They can produce yields as high as 75kg/m^2 (15lbs/ft^2) in a year.

Starter pots
In this system, the seedlings are germinated in small pots of soil, but soon their roots outgrow these pots.

Inert medium
The roots grow down through rockwool, clay, vermiculite, sand or gravel – an inert medium providing structural support, not nourishment.

Drainage channels
These allow the nutrient solution to be drained out regularly, to stop it going stagnant and keep the roots oxygenated.

Nutrient bath
A balanced solution of nutrients in water is poured into the inert medium to nourish the tomatoes' growth.

"At certain frequencies it acts as a sort of musak that can calm people and help prevent drunken brawls"

Non-lethal weapon

Cover your ears and discover how sound can be used to stop riots and brawls

To disperse crowds and prevent rioting, various forms of non-lethal weapons (NLW) are used. Among these, interestingly, is sound. Known as an acoustic or sonic weapon, infrasound (super-low frequency) and ultrasound (super-high frequency) greatly affect human ears. They can disorientate a target and have psychological effects as well as physical effects of nausea and damage to blood vessels.

Ultrasound can be increased to 120 decibels (the same volume as a jumbo jet taking off), which is considered the human pain threshold. In contrast, infrasound feels like a damaging vibration or pressure wave, as it's at a frequency too low for humans to hear. When exposed to high levels of sound, the influx of energy has a painful effect on the body.

As well as huge decibels of volume, the variations in frequency can also cause damage. For instance, an infrasound of seven or eight Hertz can rupture blood vessels. Certain types of sound within the frequencies we are able to hear also have psychological effects, acting a sort of musak that can calm people and helps prevent drunken brawls.

In New York City, piezoelectric loudspeakers are used by the NYPD. They focus sound waves in a particular direction to control large crowds. Known as Long Range Acoustic Devices (LRAD), some types can reach a maximum of 162dB. Another device is the sonic bullet. Made by inventor Woody Norris, it sends a beam of up to 145dB into its target. Prototypes are already in production to be used in the US Army to help enforce safety areas in warzones.

Long Range Acoustic Devices

Discover how this breakthrough device uses sound to its advantage

Output
The LRAD 100X is powered by a standard AC source or a rechargeable lithium battery. Its volume can reach up to 137dB.

Portability
Weighing in at a paltry 6.8kg (15lb), the 100X can easily be taken from location to location.

Range
Four to six times louder than all other systems of its size, the 100X has a range of over 600m (1,969ft) and can overcome background noise at 250m (820ft).

Materials
The 100X is made from water- and impact-resistant plastic and aluminium so it is tough enough to withstand riots and combat situations.

Uses
The system can be used for a variety of situations including law enforcement, border security, communication and even wildlife control.

The LRAD Corporation's 100X can reach volumes of 137dB while the 1000X can reach a hefty 153dB

Perfect match

Match the animal with the power of their sound (measured in decibels)

218dB

110dB

230dB


Lion


Sperm whale


Tiger pistol shrimp

Answers: 218dB = tiger pistol shrimp; 110dB = lion; 230dB = sperm whale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> *"The project came about in order to bring a bit of joy back to the area on Japan's northern coastline"*

Inflatable concert halls

Listen out for the world's first pop-up concert hall

Tuba players around the world had better take a deep breath because they might soon have to blow up their own concert halls if this incredible project is anything to go by.

Artist and sculptor Anish Kapoor and architect Arata Isozaki teamed up to create this amazing 18-metre (59-foot) high and 36-metre (118-foot) long by 29 metre (95 feet) wide structure, which held a series of concerts at Matsushima, Japan. The project came about in order to bring a bit of joy back to the group of islands on Japan's northeastern coastline, which was decimated by a tsunami after the catastrophic earthquake in 2011.

It's made of a stretchy plastic membrane that can be inflated by pumping gallons of air into it and deflated quickly. It can fit 500 audience members inside its stylish walls, as well as the orchestra. It took two years of planning and uses key parts of the local landscape in its design, such as cedar trees that were destroyed in the disaster being used for seating.

The air-conditioning system is cooled by giant blocks of ice and the revolving doors have been specially created in Germany with completely airtight seals, so no air is able to escape from inside the dome. Huge fans keep the air pushing against the PVC-coated membrane, so the entire structure doesn't collapse around the spectators.

This amazing design can fully inflate in just two hours despite its huge size. Although unlikely to replace Sydney or Moscow as the world's most iconic opera houses, it could make a massive impact with pop-up buildings in disaster areas based on the same principles.

How to inflate a concert hall

How do you make a 500-seat hall stay up?

An inflatable hall in standby mode

THE STATS
THE ARK NOVA

WEIGHT **1,700kg**
THICKNESS **0.63mm**
SURFACE AREA **2,117m^2**
AIR VOLUME **9,117m^3**
CAPACITY **500 people**
FLOOR AREA **680m^2**

DID YOU KNOW? *The Ark Nova was called that because the architects saw it as 'The New Ark', bringing hope after the floods*

Concert hall concepts

The Sydney Opera House is one of the most instantly recognisable buildings in the world. It took 16 years to build and beat competition from 232 other entries. It cost over AU$100m to build and its roof sections weigh 15 tons.

No less striking, the Bolshoi Theatre in Moscow is a symbol of Russian architecture and resilience. Burned down twice before being rebuilt into the huge structure seen today in only three years, it can seat 1,740 people.

Opened in 1778, Milan's La Scala is believed to be the finest opera house in Europe. The very first opera put on was *Europa Riconosciuta*. It has 2,800 seats, with the very top rows called the loggione – where all the fiercest critics choose to stand.

Possibly the most iconic music hall in the world is in Sydney

Acoustic cloud
This helium-filled balloon not only helps the dome stay up but also bounces sound back for acoustic assistance.

Material
A PVC-coated polyester fabric is used, as it has high tensile strength but can also be deflated easily then packed away tightly.

Seating
Seats are created from cedar trees that got knocked down during the 2011 tsunami.

Entrance
At the entrance is a tightly sealed revolving door that doesn't let air out.

The ancient Celts

How the Iron Age revolutionised this pre-Roman civilisation

The discovery of how to extract iron from its ore changed the world. As the Iron Age was born, new tools could be made for warfare, agriculture, hunting and fishing. Among the main beneficiaries of this new age were the Celts. The Iron Age in Europe lasted from 800 BCE until 43 CE and signalled a significant development of society.

Ploughs, scythes and sickles were fashioned to tend to and gather crops. Rotary querns were introduced to turn grain into flour and hunting tools became sharper and tougher. With iron, an array of swords, helmets and armour could also be fashioned. Clothing accessories developed too, with the creation of iron brooches and torcs.

The Celts lived in small farming communities, often in hill forts for added protection. The houses had thatched roofs and one of the biggest settlements in Britain was Colchester, believed to be the oldest town in Britain.

If there was a negative to the Iron Age it was in medicine. Still very primitive and led primarily by druids, one of the only surgical operations was the trepanning procedure. Headaches were believed to come from evil spirits so if you were feeling under the weather, a hole was drilled into your skull to release the demons. With the coming of the Iron Age and sharper, tougher tools, archeological evidence has shown that this gruesome practice was still popular. It seems the Celts had an obsession with the human head. They believed the head harboured the soul and that's why, after a victorious battle, they would cut off the heads of fallen enemies and display them on their houses, both as bragging rights and to warn anyone who messed with them.

A Celtic hill fort

Discover how Celtic farming communities worked

Iceni
1 Famous for being led by Boudicca, the Iceni were located in modern-day East Anglia and were a wealthy, warlike people who led many revolts against Roman rule.

Dobunni
2 This tribe was one of the largest in Britain and resided on the modern English-Welsh border. Unlike many others, the Dobunni easily submitted to Roman rule.

Dumnonii
3 Occupying Cornwall, Devon and Somerset, the Dumnonii favoured small farms over larger settlements and preferred healthy relations with Brittany in France.

Catuvellauni
4 One of the most powerful tribes, the Catuvellauni were made out of several smaller groups. Supporting Roman rule, Verulamium (St Albans) was a big Roman settlement.

Silures
5 After the Iceni, this band of Celts gave the Romans the most trouble. Originating in the valleys of South Wales, they were described as a strong and warlike nation.

DID YOU KNOW? *Female Celts had just as many rights as men. They would fight, own land and achieve status*

Construction
A roundhouse was typically constructed from a wooden frame with a straw roof.


A reconstructed roundhouse like the ones Celts lived in

Celtic cities
Celts lived in small communities led by a chieftain and a band of warriors. There were few alliances among the different tribes and no sort of centralised state or government.

Distribution
The buildings within the fort's society served different functions and roles to ensure survival and development.

Indoor fire
The indoor fire was sometimes used for extra cooking but primarily for warmth in the harsh winter months.

Hill fort location
Often surrounded by a wooden or stone wall, both natural and man-made defences made the fort tricky for enemies to breach.

Who were the Celts?

A term used for many different tribes, the Celts varied from region to region. For instance, the Gauls were based in what is now France and the Celtiberians were located in modern day Spain and Portugal. As their European influence began to come under threat from the Romans and Saxons, many migrated to Britain around 500 BCE. Despite invasions from the Romans, Angles, Saxons, Jutes and Vikings, the Celts still remained established inhabitants in many areas of Britain by the 8th century. However, their lands were now pushed back to Wales and Scotland rather than England, which was primarily Anglo-Saxon territory. Their influence can still be seen today with the uncovering of the Tal-y-Llyn hoard of Iron Age metal tools and weapons and substantial evidence of Celtic hill forts in Maiden Castle and Old Oswestry.


The remains of the Celtic hill fort at Maiden Castle

"Translated to 'Celtic Fury', it was a mass charge on the front of an enemy line"

How the Celts fought back

The Celts had a reputation for being fearsome warriors, but the advent of the Iron Age made Celtic Britain even more resistant to overseas attack than before. The mighty Roman army took three attempts to conquer Britain and continually struggled to rule over large parts of the island, especially in Scotland and Wales. The Celts had access to the technology to make their own swords, spears and axes, as well as shields for protection. According to both Greek and Roman historians, the Celts would often go into battle without armour or even completely naked, covered only in war paint. Although there is some evidence that they used helmets and body armour, these were apparently rare, possibly only used by chieftains and high-ranking warriors.

The Celtic military was primarily based around infantry, but they also used chariots and – occasionally – cavalry during battles. Their tactics weren't as advanced as the Roman testudo, for instance, but they still had some bold strategies up their sleeve. The most famous is perhaps the Furor Celtica. Translated to 'Celtic Fury', it was a mass charge on the front of an enemy line that was used to disrupt and split enemy ranks. Celts on the continent were known to be more defensive and used a tight phalanx set-up, much like the original Greek formation.

The Celtic tribes had many iconic chieftains such as Vercingetorix, Caratacus and Cassivellaunus, but the most famous, without a doubt, was Boudicca (or Boadicea). The fierce and influential warrior queen of the Iceni tribe, she led a resistance force against the Roman invaders. Successfully forming an alliance with various other clans around the British Isles, her forces defeated the Roman ninth legion and sacked the Roman-ruled Colchester, Londinium (London) and Verulamium (St Albans). Boudicca was finally defeated by Roman general Paulinus at the Battle of Watling Street, but the Iceni's stand proved that Roman rule was far from invincible.

What tools and weapons did the Celts use?

Sickles & scythes
Used to cut crops and chop wood, iron scythes and sickles made farming and building simpler and quicker.

Ploughs
The 'ard' broke up fertile soil for crops so large communities could be fed, a big reason for the Iron Age population increase.

Spears
The advent of iron smelting brought tougher and sharper spears. These helped in hunting large game and were also used in warfare.

Helmets
The Celts donned two types of helmet: the Montefortino and the Coolus. The latter was the legionnaires' helmet of choice.

STRANGE BUT TRUE
ON THE ROAD AGAIN

Who invented the first European road network?

A The Celts **B** The Romans **C** The Aztecs

Answer:
The Romans are often attributed with creating the infrastructure of Europe but recent research has shown the Celts may have preceded them. Not as long lasting or well built, Celtic roads such as the Via Heraclea still provided a transport system.

DID YOU KNOW? *The Celts didn't have a writing system, so much of what we know comes from artwork and secondary accounts*

There were other types of settlements

Hill forts were the most common type of settlement in Celtic Britain, but there were other types of communities too. In Scotland, for instance, brochs were very common. Stone was more readily available than wood in the north so hollow dry stone towers were built. A structure known as a crannog was also popular on the side of the lochs of Scotland.

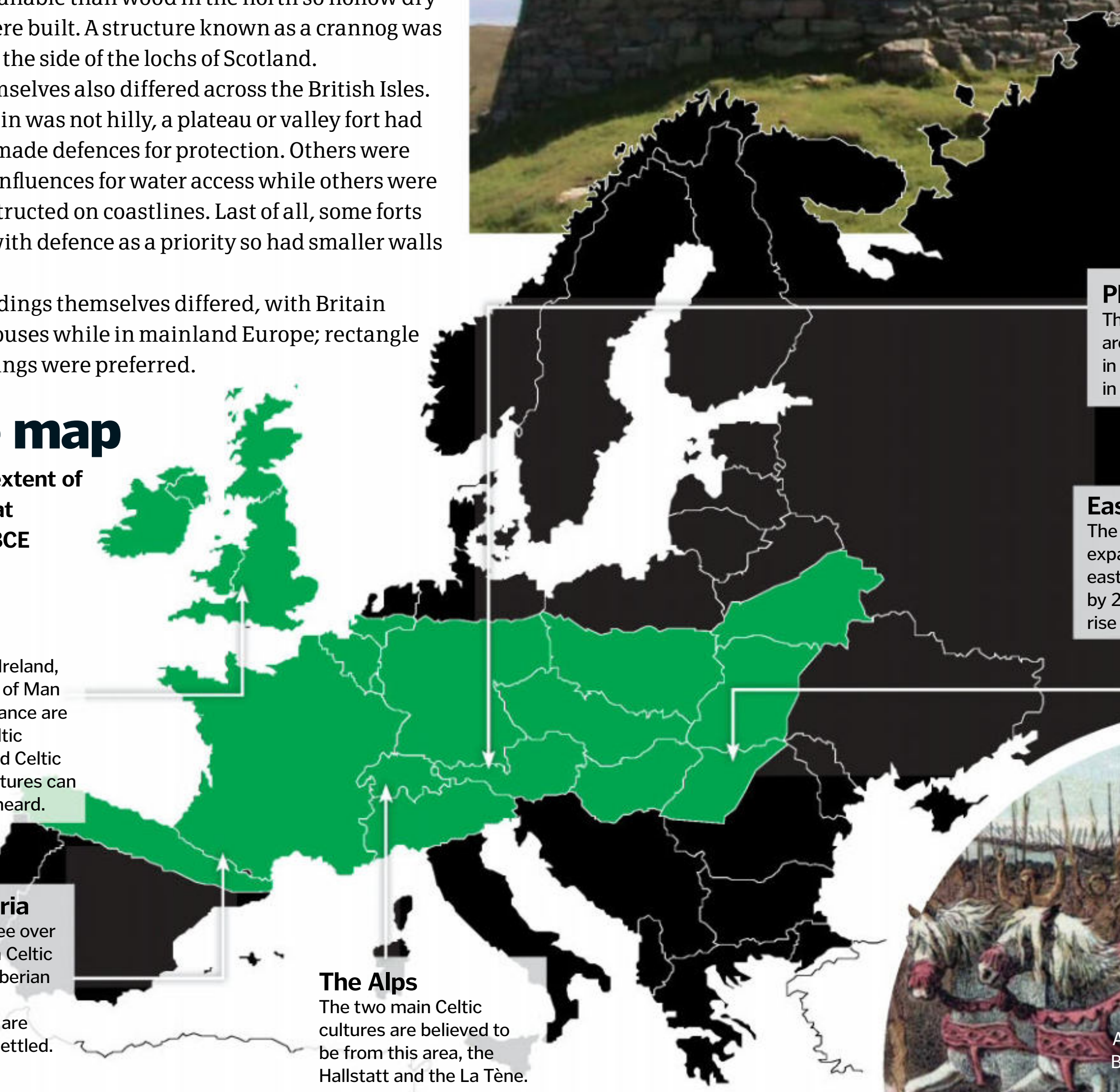
Hill forts themselves also differed across the British Isles. Where the terrain was not hilly, a plateau or valley fort had to rely on man-made defences for protection. Others were built on river confluences for water access while others were purposely constructed on coastlines. Last of all, some forts were not built with defence as a priority so had smaller walls and enclosures.

Even the buildings themselves differed, with Britain having roundhouses while in mainland Europe; rectangle or square buildings were preferred.

The Dun Carloway broch on the Isle of Lewis, Scotland. It is one of the best preserved in the world

On the map

■ The largest extent of Celtic lands at around 275 BCE



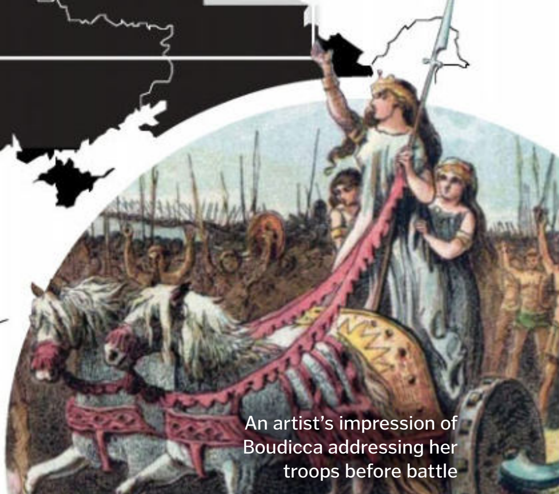
Place of origin
The Celts originated in an area known as 'Hallstatt' in the foothills of the Alps in modern-day Austria.

East expansion
The extent of Celtic expansion reached as far east as parts of Romania by 275 BCE before the rise of the Roman Empire.

British Isles
Scotland, Wales, Ireland, Cornwall, the Isle of Man and Brittany in France are known as the 'Celtic Nations' where old Celtic traditions and cultures can still be seen and heard.

Gaul and Iberia
Historians disagree over the likelihood of a Celtic presence on the Iberian Peninsula where 'Lusitanian Celts' are thought to have settled.

The Alps
The two main Celtic cultures are believed to be from this area, the Hallstatt and the La Tène.



An artist's impression of Boudicca addressing her troops before battle

Longer swords
As iron and steel production techniques gradually improved, longer, double-edged and better balanced swords became a popular weapon of choice in Celtic warfare.

Falcata sword
A typical Celtic sword used in the Iberian Peninsula. A short sword used for quick slashes, it delivered a powerful blow and could split enemy shields and helmets.

Armour
Known as Ceannlann, it was a mixture of linen and metal scales sewn onto chain mail armour. Nobles and rich Celts could afford this, while poor warriors wore leather armour or none at all.

Ranged weapons
The Celtic infantry focused on close-quarters combat, but after witnessing Viking bows, they began to occasionally use slings, bows and spears for attacks from a distance.

"Usually, peasants would stay peasants for life, but a court jester would usually be from the lower classes"

Court Jesters

Fooling around with the funniest guys of the medieval world

Back in the days when the kings and queens of Britain had to rule a warring and volatile empire, laughter was in short supply. Therefore, the role of a court jester was massively important for making a monarch smile and ensuring a load of people didn't get their heads chopped off by a grumpy ruler.

Dressed in bright, gaudy colours, wearing a ridiculous hat and often holding a sceptre, the jester would perform at the monarch's request, dancing, singing, telling jokes and doing impressions. He would also be made to perform at meal times because it was believed that cheerfulness aided digestion.

Jesters held a huge position of importance and privilege in the house of a monarch, being able to mock figures of authority in a way that would have resulted in severe punishment for anyone else.

The role of court jester was one of the few that allowed for social mobility in the Middle Ages. Usually, peasants would stay peasants for life, but a court jester would usually be from the lower classes, as they would provide a fresher and more amusing perspective than a fellow member of the upper classes. This line of work was also pretty much the only one at the time in which having a physical deformity was considered a bonus!

Court jesters were allowed to poke fun at the royalty, something punishable by death if someone else did it

Rib-ticklers and riddles from the past

Q: What's black when you get it, red when you use it and white when you throw it away?
A: Charcoal

Q: Say my name and I disappear. What am I?
A: Silence

Q: My life can be measured in hours. I serve by being devoured. Thin I am quick. Fat I am slow. Wind is my foe. What am I?
A: A candle

A harlequin costume, not unlike many jester costumes of its age

Roman currency

How did the Romans do their grocery shopping?

When the Roman Empire first began to establish itself, the main system for the transfer of goods was bartering, basically a trade where people had to establish the worth of an item on the spot.

The value of a cow then became the standard from which all other products took their value. Because of this, a small bronze coin became worth the value of a cow and that could be traded as well, with markings on these coins become common around the 3rd century BCE. This was called an 'as' and became the first recognised coin in the Roman Empire.

The realisation that not everything was worth the same amount as a cow led the Romans to chop the as into smaller bits, so less valuable items could be traded using coins. The Greeks inspired the Romans to introduce a silver coin called a denarius, which was worth ten ases.

Finally, the Romans advanced onto a gold coin called an aureus, with one of these valuable pieces worth 25 denarii and a whopping 250 ases, meaning that one aureus could buy 250 cows. Then it was just a matter of finding where to put them all!

Romans were among the first to establish a standardised currency

DID YOU KNOW? *Cinema chain's ODEON name reportedly stands for 'Oscar Deutsch Entertains Our Nation', after its founder*

The first cinemas

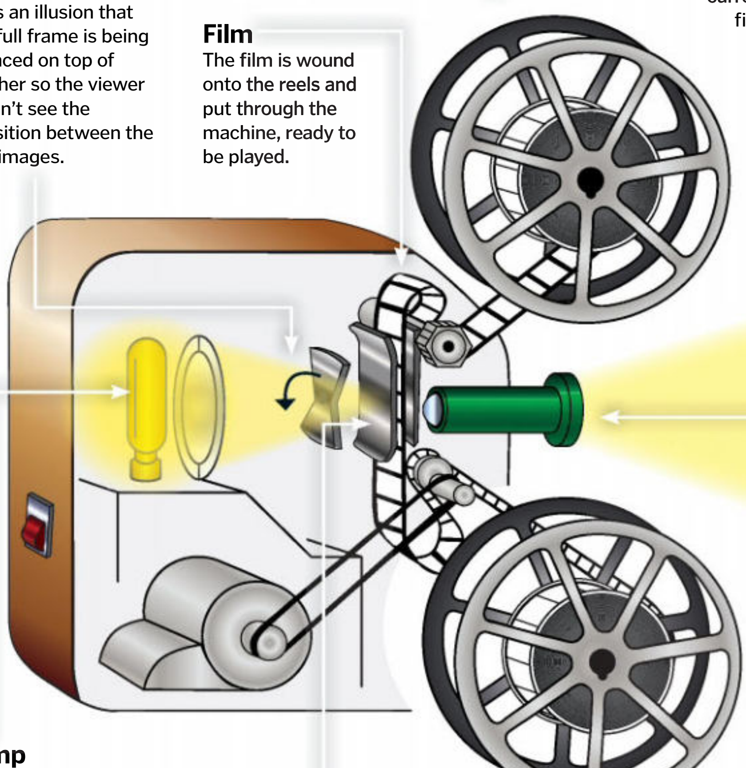
The technology inside a projectionist's booth

One of the first working projectors was constructed by renowned US inventor Thomas Edison in the 1890s. Known as a kinetoscope, it was not strictly a movie projector as we know it but was an early demonstration of images being put onto a screen. This idea was then taken further and as the new century began, cinema exploded onto the social scene. Exploded was an apt word, as the first type of film was made out of highly flammable cellulose nitrate. Strong and transparent, it was ideal for film projection but its major drawback was exposed by a theatre's limelight stage lighting. After prolonged contact, it would burn or even explode while belching out toxic nitrogen gas. As a result, by the 1950s, cellulose triacetate had effectively replaced the older film. This had a much lower flammability rate but was still liable to melting and degrading under hot and humid conditions. From the 1970s, these issues were amended by the introduction of polyester film, which was stronger and more heat resistant and is still used today.

From the turn of the 20th century until the 1960s, a carbon arc lamp was the projector's light source, but have since been replaced by xenon arc bulbs. Xenon bulbs could stay lit for much longer than their carbon counterparts. As cinema progressed, composite colour films and new widescreen aspect ratios appeared in the 1950s. Dolby Digital 5.1 stereo sound, which is the standard for modern DVD technology, was incorporated from 1992 onward. Today, cinemas are generally working toward an all-digital projection system.

Inside a projector

How films are put onto the big screen



Rotating shutter
The rotating shutter gives an illusion that one full frame is being replaced on top of another so the viewer doesn't see the transition between the two images.

Film
The film is wound onto the reels and put through the machine, ready to be played.

Digital evolution
In the future, most projectors will incorporate an all-digital system that will do away with film. The process to digital is currently under way but many film projectors still remain.

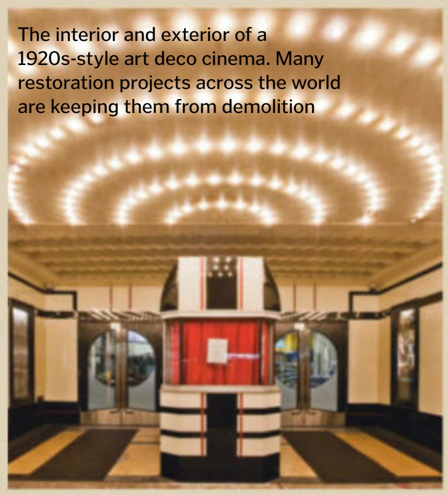
Lamp
A lamp lights the film when it goes through the gate, ensuring the images are properly lit for the viewer.

Gate
The image goes through the 'gate area' where the light shines and illuminates the image for projection.

Lens
Mirrors within the mechanism intensify the light from the lamp to improve the picture before it is shown to an audience.

The expansion of world cinema

The first movie theatre is believed to have been the Wintergarten in Berlin, which staged a film production by the German Skladnowsky brothers in 1895. This was closely followed by the French Lumière brothers' 'cinematographe' mechanism, which debuted at London's Marlborough Hall of the Royal Polytechnic Institution. From here on out, cinemas began to spring up in towns and cities with the UK's first chain the Provincial Cinematograph Theatres (PCT) constructing cinemas nationwide. Between the world wars, a style of architecture known as art deco began to dominate the film scene and many theatres were built in this design. A poignant reminder of interwar life, they are very different to the multiplexes of today and groups such as the Cinema Theatre Association have been set up to draw attention to their conservation. Since the 1960s and the end of the Golden Age of Hollywood, multiplexes and IMAX theatres have begun to dominate the cinema scene, showing 2D, 3D and even '4D' films all around the world.



The interior and exterior of a 1920s-style art deco cinema. Many restoration projects across the world are keeping them from demolition

"It was named after William Tecumseh Sherman, who was a Union general in the Americal Civil War"

The Sherman Tank

How this famous tank led the Allied war machines in WWII

The first use of the tank as a military weapon was in the First World War at the Battle of the Somme. Armoured vehicles would become a big part of warfare but it wasn't until the Second World War that they became essential. The most essential of all the Allied tanks was the Sherman.

Titled the M4 Medium Tank, it was named after William Tecumseh Sherman, who was a Union general in the American Civil War. It replaced the M3 armoured vehicle and was provided as part of the American Lend-Lease policy to its allies. It was first used in 1942 by the British, to tussle with the German Panzer IIIs and IVs for battlefield supremacy.

The Sherman was based on speed and manoeuvrability. It had weaker armour and less equipment than its German counterparts and with the introduction of the Axis' Tiger and Panther models, it became inferior on the battlefield. This was soon remedied with the introduction of the Firefly, Jumbo and Easy Eight variants. The tank's main tactic was to fire an armour-piercing round and then incinerate the unarmoured and exposed enemy tank. Shermans were always fielded in great numbers and worked well in partnership with M10 Tank Destroyers. The Sherman was used extensively in the African, French and Italian campaigns until the end of the war. Some models could attach a flamethrower, rocket launcher or bulldozer blade, as well as amphibious versions, which were used in the D-Day landings.

Even after the war, the Sherman was still used frequently. Its reliability and low running cost allowed it to be deployed in the Korean War, as well as by other nations, with Australia, Brazil and Egypt and many more having their own variations of the successful Sherman model.

The statistics...

M4 Sherman

First year of service: 1942

Amount made: 50,000

Crew: Five

Length: 5.84m (19.16ft)

Width: 2.62m (8.6ft)

Height: 2.74m (8.99ft)

Max speed: 48km/h (30mph)

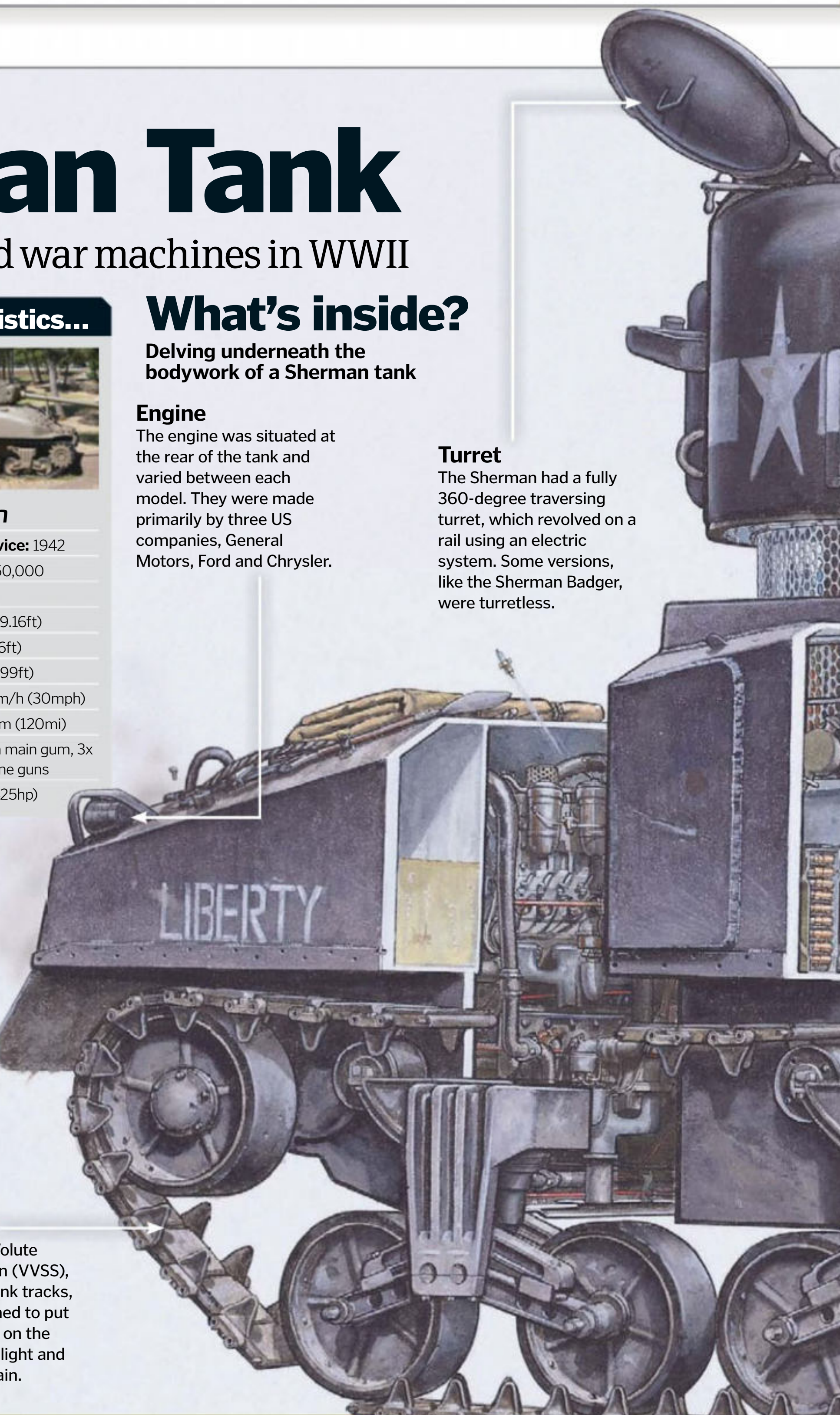
Max range: 193km (120mi)

Weapons: 75mm main gum, 3x machine guns

Engine: 317kW (425hp)

What's inside?

Delving underneath the bodywork of a Sherman tank



Engine
The engine was situated at the rear of the tank and varied between each model. They were made primarily by three US companies, General Motors, Ford and Chrysler.

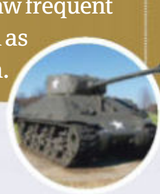
Turret
The Sherman had a fully 360-degree traversing turret, which revolved on a rail using an electric system. Some versions, like the Sherman Badger, were turretless.

Tracks
Using a Vertical Volute Spring Suspension (VVSS), the tank had 78-link tracks, which was designed to put minimal pressure on the ground to keep it light and nimble on all terrain.

The various members of the Sherman tank family

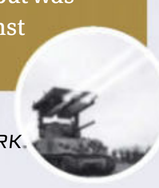
1 M4A3E2 Jumbo
Designed for the liberation of Europe, the Jumbo weighed 38 tons, it was very well protected, resisting all German anti-tank guns.

2 M4A3E8 Easy Eight
Smaller and more mobile yet with the same armour as the Jumbo, this variant saw frequent postwar service, such as in Korea and Vietnam.



3 M4A3R3 Zippo
Known as a 'flamethrower tank', designed to flush out pillboxes and bunkers. It was mainly used in the Far East theatre of war.

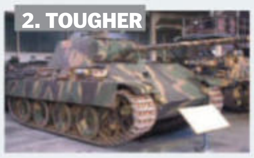
4 T34 Calliope
Carrying a rocket launcher, this tank only came into use at the tail end of WWII but was highly effective against fortified defences.



1. TOUGH

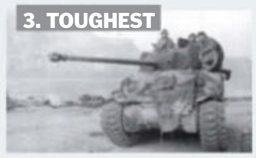
T-34
The T-34 was a heavily armoured Soviet battle tank with good firepower. The trusty and durable T-34 is still used by some countries today.

2. TOUGHER



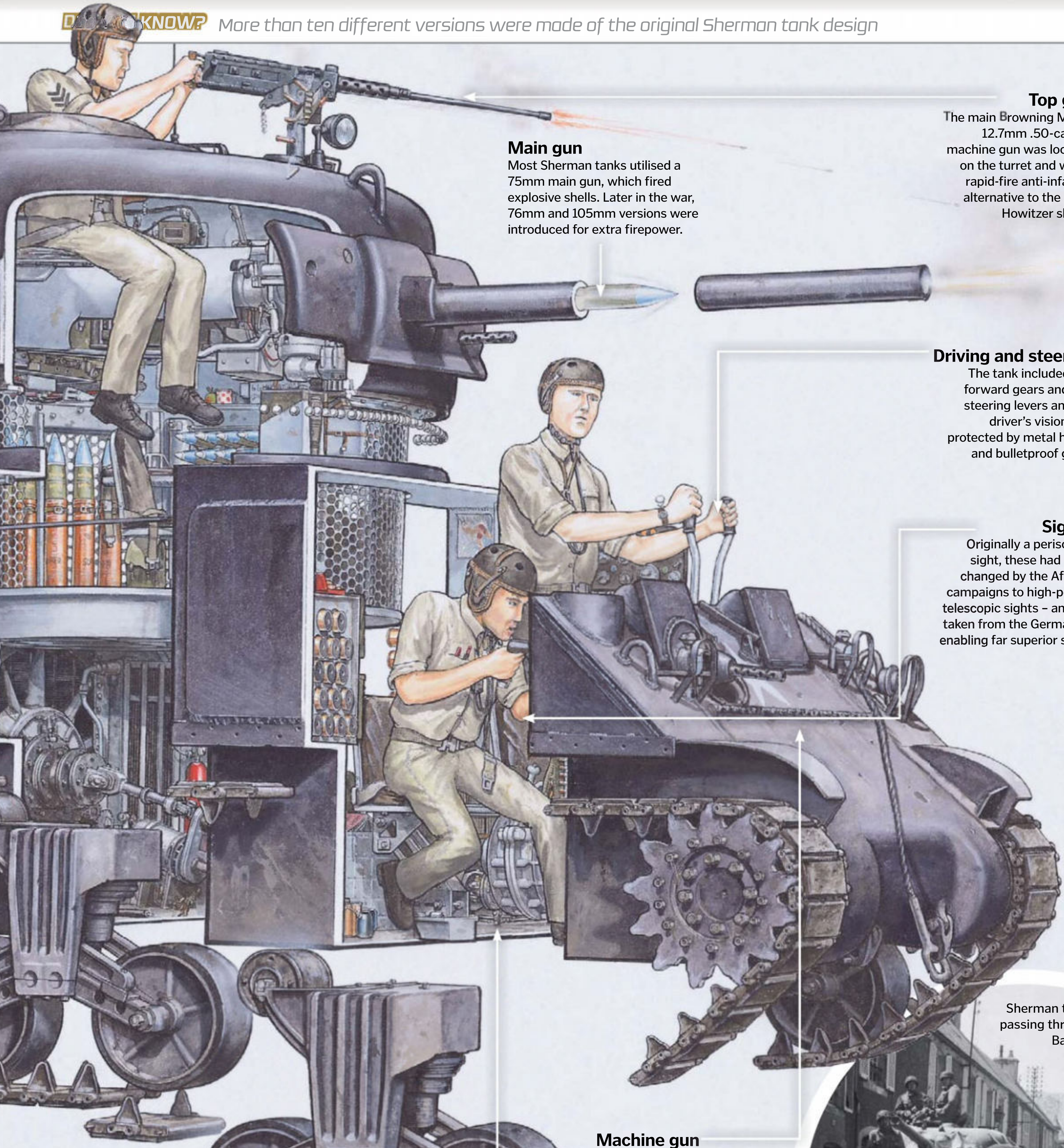
Panther
This German tank's protection was so tough that it was still used as standard by several other nations around the world after the war.

3. TOUGHEST



Firefly
Designed by the British, it was the only Allied tank that could take on the fearsome German Panthers and Tigers and have a hope of winning.

DID YOU KNOW? *More than ten different versions were made of the original Sherman tank design*



Top gun
The main Browning M2HB 12.7mm .50-calibre machine gun was located on the turret and was a rapid-fire anti-infantry alternative to the main Howitzer shells.

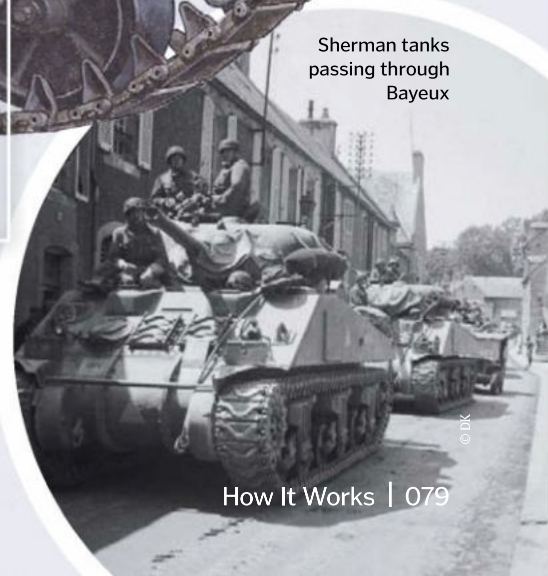
Main gun
Most Sherman tanks utilised a 75mm main gun, which fired explosive shells. Later in the war, 76mm and 105mm versions were introduced for extra firepower.

Driving and steering
The tank included five forward gears and two steering levers and the driver's vision was protected by metal hoods and bulletproof glass.

Sights
Originally a periscopic sight, these had been changed by the African campaigns to high-power telescopic sights – an idea taken from the Germans – enabling far superior sight.

Escape hatch
To allow for quick escapes after sustaining damage, later models included an emergency hatch on the floor below the bow gunner.

Machine gun
The bow gunner had a 7.62mm .30-calibre machine gun to strike closer and faster infantry. It was protected by a reinforced sloped front hull.



Sherman tanks passing through Bayeux

BRAIN DUMP

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MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in zoology and another in real-time computing. He's been writing about science and technology since before the web. His science-fiction novel, *A Jar Of Wasps*, is published by Anarchy Books.

Crispin Andrews

Crispin is a freelance writer and history graduate. He likes cricket, Sherlock Holmes, Carl von Clausewitz and pine martens. He has never watched reality TV and has no interest in Cheryl Cole's handbag.

Alexandra Cheung

Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

Laura Mears

Laura studied biomedical science at King's College London and has a masters from the University of Cambridge. She escaped the lab to pursue a career in science communication. She spends her spare time developing educational video games.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

How many insects have been discovered so far?

Caitlyn Taylor

■ The total number of named species is around a million. But it's very hard to tell how many species have been counted twice. The differences between some species can be a matter of an extra antenna segment here, or longer bristles on an abdomen there. Not only is it easy to make mistakes, but it is also difficult to verify old records without going back into the field and reexamining living specimens. This isn't important enough to justify the amount of effort it would require from entomologists. The total number of undiscovered insect species is an even bigger guess. Scientists make extrapolations based on the rate at which new species are reported each year or the number of new species found per hectare of rainforest. Estimates of this total vary from 2 million to 30 million, meaning we have discovered between three and 50 per cent of insect species. **LV**

How does SONAR work?

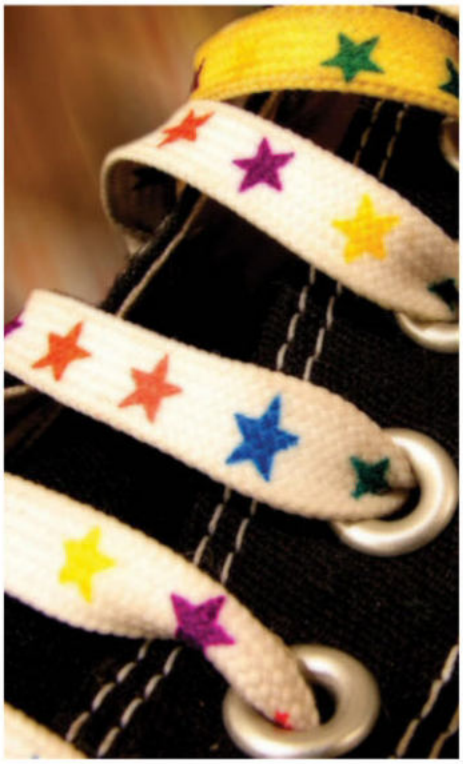
Barry Wilson

■ Sonar basically uses echoes. Sound waves are sent out and bounce off objects, reflecting back to the originator of the sound. Animals like dolphins and whales, as well as man-made equipment, can use these waves to gather information about objects such as their distance, location, shape and movement. The acronym SONAR was coined in World War II, standing for SOund Navigation And Ranging. Military radar can cover thousands of miles and dolphins can tell the difference between objects of different shapes, sizes, speeds and even what they're made of. **SF**

When did people start putting shoelaces on their shoes?

Ifan Wright

Roman soldiers' sandals had leather straps and Ancient Greeks used rawhide lacing, but no one really knows who started it. In 2000 BCE, Mesopotamians bound pieces of leather to their feet and ankles with laces. A 5,500-year-old shoe with laces was recently discovered in a cave in Armenia. In 1790, Harvey Kennedy patented the shoelace. He threaded the lace through an eyehole and placed an aglet on the lace so it didn't fray. It made him a fortune, but the original inventor of shoelaces was probably a clever hunter, gatherer or warrior, more than 30,000 years ago, when humans first started wearing shoes, who got fed up with theirs falling off. **CA**



What is gamma radiation?

Jaime Edwards

Gamma radiation is a type of electromagnetic radiation produced inside radioactive atoms. It has a very short wavelength and carries large amounts of energy. Gamma rays are hard to stop and, unlike alpha radiation, can penetrate skin. When they pass through matter, they knock electrons off their atoms, a process called ionisation, which is harmful to living organisms. Gamma radiation is used to kill cancerous cells during radiotherapy. The gamma rays emitted by nuclear reactions inside supernovas or distant stars allow astronomers to receive information from the outer reaches of the universe. **AC**

How do oxbow lakes form?

Kacey Ward

Natural meandering in a slow-flowing river's course exaggerates over time because the current will tend to erode on the outside edge of a loop and deposit sediment on the inside. This widens the loops until they almost double back on themselves. Then a flood washes away the narrow bank separating these loops and the river bypasses the loop altogether. The connections to this isolated loop silt up and you are left with a crescent-shaped lake, known as an oxbow. **LV**

COOL FACTS

We owe time-measuring units to ancient Babylonians

We inherited the tradition of measuring time in units of 12 to the Babylonians, whose numerical system used a base of 60. There are roughly 12 lunar cycles in a year, which may explain why we divide years and days into 12.

What is the rarest element on Earth? Find out on page 82

BRAIN DUMP

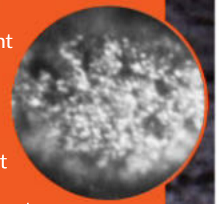
What would happen to your body if the force of gravity was doubled?

Vincent Cooper

■ Doubling gravity would put your body under a great deal of stress and could be fatal if you were exposed to it for a protracted period. Firstly, your joints and skeleton would strain to support your increased weight. Your muscles would struggle with even small movements. But one of the most dangerous effects would be on your heart. Stronger gravity would cause blood to pool in your extremities, making your heart work extra hard to keep the blood pumping around your body. Your blood pressure would have to double to overcome the increased gravity. Other processes inside the body might also be affected. Over time, very fit individuals might adapt and build stronger bones and muscles but any injury or illness would be difficult to recover from. Falls would be particularly dangerous. People who were less fit, overweight or affected by other health conditions would be unlikely to survive a long exposure to double gravity conditions. **AC**

COOL FACTS

The rarest element on Earth



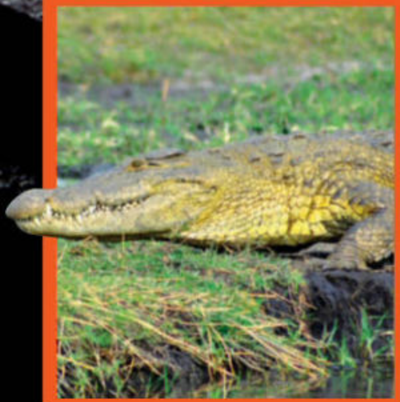
Earth's rarest element is berkelium, discovered in 1949 and named after the city of its discovery: Berkeley, California. It is produced in extremely small amounts in certain nuclear reactors, and it has no practical applications other than scientific research.

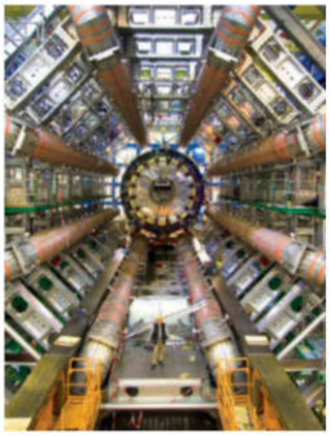
Opera singers reach a higher frequency

An orchestra is loudest at a frequency of around 500Hz, the same as the human voice. But by manipulating their voice, opera singers can produce harmonics at much higher frequencies, around 3000Hz, allowing them to be heard over the instruments.

Crocs and gators differ by a nose

While alligators generally only have their upper teeth visible outside their mouth when it is shut, crocodiles have some of the lower teeth exposed as well. Alligators also have a more rounded snout.





Why does the CERN particle collider have to be so big?

Oliver Moore

The Large Hadron Collider's colossal size limits the energy lost by particles as they hurtle around its 27-kilometre (16.8-mile) ring. The advantage of circular colliders is that they allow particles to zip around and around, with powerful magnets nudging them up to higher and higher speeds with each lap. But the change in direction as they bend around the track causes them to lose energy. The smaller the circle, the tighter the curve that the particles must follow and the more energy they lose. The LHC's gentle curves allow particles to reach almost the speed of light. **AC**

What is humidity?

Lana Hill

Water boils at 100 degrees Celsius (212 degrees Fahrenheit) to produce steam, but even at lower temperatures there will always be some molecules of water that acquire enough energy from random collisions to escape the liquid state; water vapour is just colder steam. High humidity feels uncomfortable because your sweat doesn't evaporate, but very low humidity is just as bad because we get dehydrated. We usually measure humidity as a percentage of the maximum amount of water vapour the air will hold at that temperature and around 50 per cent is most comfortable for us. **LV**

What were trebuchets and how did they work?

Sebastian King

It's a siege catapult, used by invading armies across Europe, in China and central Asia between the 12th and 16th centuries. Also in China and central Asia. Threw projectiles at, into and over, castle walls.

Imagine a big see-saw with the pivot near one end. That created a very long arm with a sling on the end, in which were placed rocks, iron balls, debris, sometimes even manure and plague corpses. At the pivot end was a much heavier counterbalance, usually a container full of rocks and iron pellets. To fire, soldiers pulled down on the arm until it was horizontal. This lifted the counterbalance, which fell back to Earth when they let go, jolting the arm back to the vertical and firing the projectiles toward the enemy. **CA**

How high up is the lowest level of the Earth's atmosphere?

Daisy Watson

The lowest level of the Earth's atmosphere is the troposphere, and it goes from the surface to an average altitude of 12 kilometres (7.5 miles). However, its altitude varies depending on where you are on Earth – it can be as low as eight kilometres (five miles) at the poles and as high as 16 kilometres (ten miles) at the equator. The troposphere is heated by the Earth's surface and most of its heat is concenrated in the lowest part. Earth's weather activity also takes place in this layer, and it contains about 80 percent of the entire atmosphere's mass. **SF**

Just how rich is Queen Elizabeth II? Find out on page 84

How rich is Queen Elizabeth II and where does she get her money from?

Adam Mitchell

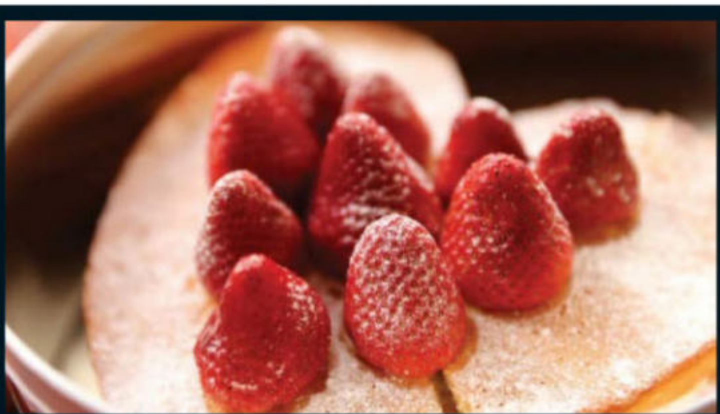
According to the 2014 *Sunday Times* Rich List, the Queen is worth an estimated £330 million ($562 million), making her the 285th wealthiest person in Britain.

The official duties of the Royal Family are funded by the Sovereign Grant; a yearly bursary from the government. In the financial year of 2012-2013, the grant amounted to £31 million ($52.8 million). The Queen receives a yearly income from the Duchy of Lancaster; a portfolio of properties held on her behalf, providing an additional net income of £12.8 million ($21.8 million). On top of this, she has a private investment portfolio, and a personal income of unknown magnitude. She isn't as expensive as she might appear. In 1760, King George III made an agreement with the government that he would turn over the profits from all Crown-owned land, in return for an annual income. The Queen still honours this agreement, and in 2013, over £252 million ($429 million) in profits from the Crown Estate were returned to the Treasury. **LM**

COOL FACTS

The tiniest dinosaur of them all

Mei long, a feathered troodontid found in China, was about 53cm (21in) long. Even smaller was the Epidexipteryx, which was 25cm (10in) long based on a partial skeleton, similar in size to a pigeon.



How does self-raising flour work?

Fabian Martin

In order to make a cake rise, you need bubbles, and in order to make bubbles, you need a raising agent.

Self-raising flour contains baking powder, which is a combination of bicarbonate of soda and an acid. These react to produce bubbles of carbon dioxide. Most kitchen acids, like vinegar or lemon juice, would spoil the taste of a cake, so instead, the reaction is triggered by cream of tartar. This powder is mildly acidic and as the cake batter is mixed, it dissolves, reacting with the slightly alkaline bicarbonate of soda, creating bubbles. In the heat of the oven, the gas inside the bubbles expands, causing the cake to rise. **LM**

What exactly is rust?

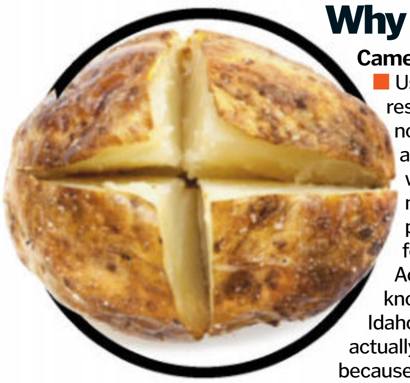
Lacy Young

Rust is a combination of hydrated iron oxides. A coating of paint protects the frame of a steel bike, but if the paint is scratched, the shiny surface of the metal beneath is revealed. When it rains, droplets of water settle on the steel, and dissolved oxygen begins to eat away at the iron. It reacts with the metal, oxidising it and producing free electrons. These attract hydrogen ions from the water, leaving hydroxide ions (OH^-) behind, and raising the pH. The hydroxide ions react with the oxidised iron, producing colourful hydrated iron oxides, known as rust. **LM**

Why are ships called 'she'?

William Anderson

■ Some say it's because the men revered their ship like a goddess or religious icon. Columbus named his ship, Santa Maria, after the Virgin Mary. Seafarers relied upon their ship to nurture them, keep them nourished, like their wives and mothers. It was considered bad luck to have women on board, so ship owners used their loved ones' names to keep them in mind. There is another less romantic possibility, though. In some European languages, nouns are considered to be either masculine or feminine. Some believe the word ship was just one of the feminine words. **CA**



Why are aluminium-baked potatoes crispy?

Cameron Jones

■ Using aluminium foil usually results in a softer-skinned potato, not a crispy one. Potatoes are about 80 per cent water, so wrapping them up traps moisture inside and steams the potato. Some people think the foil makes potatoes bake faster. According to Don Odiorne, also known as "Dr Potato", from the Idaho Potato Commission, it can actually slow down the cooking time because the foil has to heat up first. Restaurants first started wrapping potatoes in foil to disguise blemishes and dress them up a bit. It's best to bake potatoes without wrapping them in foil. Put them in the oven at 200°C (392°F) for 45 to 60 minutes, or use a food thermometer to check when the potato's internal temperature reaches 100°C (212°F). Be sure to poke several holes in them first to allow moisture to escape. To get a crispy-skinned potato, dry the skin well after washing, lightly coat it with oil, and sprinkle with coarse salt before baking. **SF**

What was the fastest round-world trip?

Thomas Harris

■ According to the Guinness World Records, the fastest aerial circumnavigation (without going into space) still belongs to Concorde. In 1995, the supersonic passenger jet set off from New York, USA and circled the globe in just 31 hours, 27 minutes and 49 seconds, reaching Mach 2 - twice the speed of sound. The historical flight was made as part of an event to celebrate the anniversary of Christopher Columbus' discovery of America. Steve Fossett set the solo record in 2005 in Virgin Atlantic's GlobalFlyer. He flew 37,000 kilometres (22,991 miles) in 67 hours, two minutes and 38 seconds, without stopping to refuel. **SF**

Why are vacuum cleaners so noisy?

Richard Ecclestone

■ Vacuum cleaners only create a partial vacuum, and in doing so produce vibrations that result in noise levels of around 80 decibels. Inside, a powerful fan spins at a very high speed, pulling air outward and producing a partial vacuum at the centre to draw in air, dust and dirt. The fan causes the appliance's casing and parts to vibrate, as does the turbulent airflow created. By using new component materials, air duct designs and using mufflers, manufacturers have produced quieter vacuum cleaners, with the latest clocking in at 61 decibels. Even quieter appliances are technically possible, but they would be too expensive to be commercially viable. **AC**

Why do bats sleep upside down?

Karen Scott

■ This probably evolved as an adaptation to cave dwelling. Once you have evolved echolocation, you can find your way around in total darkness - unlike most of your predators, which need at least some light to find you. So the back of a cave is a safer place to roost than the branches of a tree. And the ceiling of a cave is much safer than the floor. This position also allows them to easily spread their wings for flight when they wake up. Most bats are unable to take off from the ground as their wings don't produce enough lift. **LV**

New Brain Dump is here!

■ Don't miss issue 14 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 1 July. Inside, you'll discover all about how diamonds are cut, how people walk over scalding hot coals and why camels have humps. It's packed with science, history and technology snippets, including five cool things to know about the human heart, which creature lives deepest underground and the answer to the question: will we ever be able to teleport? Download the new issue of **Brain Dump** on the first day of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is @BrainDumpMag.

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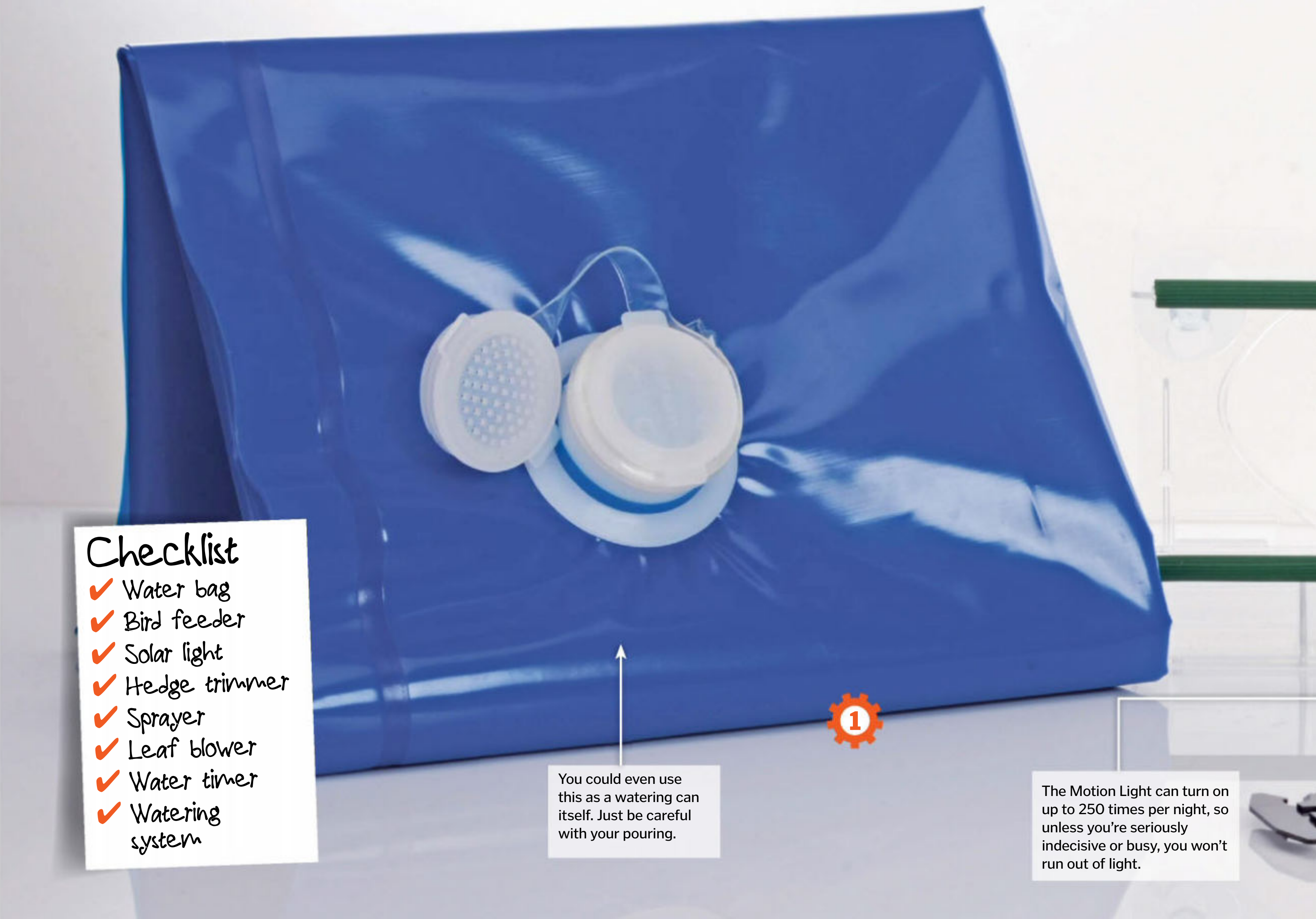
REVIEWS
All the latest gear and gadgets

Garden gadgets

Embrace your green fingers with these gardening gizmos

You might think a watering can and a bladed lawn mower is all you need to keep your garden in check, but not any more. Now there's a wealth of gadgets to make your humble backyard your own personal vacation paradise – right at home.



Checklist
- ✔ Water bag
- ✔ Bird feeder
- ✔ Solar light
- ✔ Hedge trimmer
- ✔ Sprayer
- ✔ Leaf blower
- ✔ Water timer
- ✔ Watering system

You could even use this as a watering can itself. Just be careful with your pouring.

The Motion Light can turn on up to 250 times per night, so unless you're seriously indecisive or busy, you won't run out of light.

1 Water carrier

H2GO Bag
£10.95 / $19.99
www.gizoo.co.uk
This is designed to save endless trips to and from the water butt. Pop the mat on the base of your wheelbarrow, put the bag in and fill it with up to 80 litres of water to carry around buckets of liquid in one trip. Not the most hi-tech gadget, but well designed and hugely useful.
Verdict:

2 Bird bistro

Window Bird Feeder
£9.95 / $N/A
www.gizoo.co.uk
The innovative design protects birds from predators, as the casing gives them a clear view of what's coming. It takes seconds to put together and the suckers and string make it easy to attach anywhere. There's three-sided access and the ability to hold water and birdseed.
Verdict:

3 Night light

Eco Wedge Solar Motion Light
£19.95 / $N/A
www.gizoo.co.uk
This solar-powered light is tiny but mighty at just 11.5cm (4.5in) high but shines with the power of a 50W bulb. It works just as well in winter as it does in summer, so even with the nights drawing in, this light will still do the business just fine.
Verdict:

4 Time for a trim

Shear Shrubber
£50.62 / $N/A
www.maplin.co.uk
The Black & Decker Shear Shrubber can be both a trimmer and an edger. Being Black & Decker, you expect a quality product and it doesn't disappoint. It's lightweight at an effortless 0.65kg (1.4lb), which shouldn't be a problem for anyone to hold, even if you do have a big garden.
Verdict:

The Matabi Kima Sprayer uses viton seals to ensure nothing escapes from the canister.

You can fit the timer onto 1.27cm (0.5in), 1.9cm (0.75in) and 2.5cm (1in) tap sizes, so it should fit most hoses.

The system delivers 7l (1.8ga) every ten minutes, while a hose would pump out 91l (24ga).

The powerful and fast-mulching blades reduce the leaves down by a ratio of 15:1, so it can pick up 675l (178ga) worth of leaves.

The green strips on the roof and base make the feeder visible to birds to minimise the chance of accidental collision.

The 1.2Ah Lithium-ion battery only lasts an hour, and takes 16 hours to recharge – so trim wisely.

EXTRAS

Gardening-themed entertainment

BOOK

The Machine In The Garden

Price: £13 / $19.95
Get it from: amazon.com
This fascinating book looks at the links between the evolution of technology and farming practices in the USA and how each has affected the other.

APP

RSPB eGuide To British Birds

Price: £4.99 / $7.99
Get it from: iTunes / Google Play
An interactive companion to the RSPB's *Handbook Of British Birds*, it includes images, maps, calls and descriptions of nearly 300 bird species from the British Isles.

WEBSITE

rhs.org.uk

This website from the RHS (Royal Horticultural Society) can find thousands of plants in seconds. If you can only remember part of its English or Latin name, *Plant Finder* will help you track down that mystery flower.

5 Under pressure

Matabi Kima Sprayer
£42.22 / $N/A
www.maplin.co.uk
If you need flexibility while walking around your garden, this is the tool for you. You can put anything in here, from water to weed killer in order to combat those problem plants. Spray your desired area with the ergonomic handle and kiss extension cables goodbye.
Verdict:

6 Blown away

Ryobi Electric Blower
£85.61 / $N/A
www.maplin.co.uk
The Ryobi is a great tool. It can blow leaves at an incredible 320km/h (200mph), giving even the most stubborn leaf a reason to move, and if you're sucking up, it'll hold 45l (12ga) of mulched leaf. At only 5.5kg (12lb), you can keep going as long as you like.
Verdict:

7 Constant gardener

Hozelock Water Timer
£40.19 / $N/A
www.maplin.co.uk
This gadget will do all your watering for you. All you need to do is set the timer to water as often as you like and it'll get your sprinkler system splashing automatically. Once you've set the watering time and number, you have nothing more to do but watch the grass grow.
Verdict:

8 Efficient watering

Hozelock greenhouse watering kit
£47.18 / $N/A
www.maplin.co.uk
Apparently we use far too much water when we're feeding our plants, but it turns out we can save an incredible 90 per cent of our usage with the automatic watering system. It sets up in just five minutes and delivers water straight to your plants when it's needed.
Verdict:

GROUP TEST
Putting products through their paces

Timeless watches

Timepieces that do more than just tell the time

1 Samsung Gear 2

Price: £249/$299.99
Get it from: www.samsung.com
If you already own a Samsung mobile device, we'd be surprised if you looked much further than the Gear 2 for your choice of smartwatch. It's sleek, suave, would not look out of place at a fancy dinner party, and holds all the tech you could ever want. This is the closest we've actually felt to being James Bond.

It comes with a two-megapixel camera, 4.14-centimetre (1.63-inch) Super AMOLED display, pedometer and the ability to play music on the go. You can also turn it into a remote control for your TV – which is definitely a life-changer – you can read text messages, make hands-free calls and screen your calls to find out who's calling you while your phone's still in your pocket. And, as every watch should, it tells the time.

Obviously, this product is only handy for someone with an accompanying Samsung device, but if you do have one, then this should definitely be on your to-buy list. The only other slight downside, and we're nit-picking here, is the large buckle on the wrist strap digs in a bit if you're resting your wrist on the desk for an extended period of time. We love the functions and the sync-up is incredibly easy with video tutorials to help you along.
Verdict:

2 Nite ICON-209L

Price: £300/$435
Get it from: www.nitewatches.com
At first glance, the ICON-209L is a gorgeous-looking timepiece. It has a clean, functional face, prominent crown and a comfortable leather strap that just oozes class and sophistication.

Delve into the technology and you see it's even cooler. It doesn't have any bells or whistles like a stopwatch, timer or alarm, but what it does house is GTLS technology. This is a tritium-phosphor blend that is entirely self-powering and allows the ICON-209L to glow in the dark.

The watch has a battery life of 45 months and that can be extended even further by removing the crown when it's not to be used for a while. It is also waterproof to a depth of 100 metres (328 feet), but you will have to give it a rinse if you've been swimming in salt water.

We really like this watch because it teams style with awesome chemistry, but if we had to find a criticism we would like the glow-in-the-dark element to be something you are able to turn on and off, because there are times when it did become a tad annoying to always have a glowing wrist when it got dark.
Verdict:

3 Kisai Rogue Touch Silicone LCD Watch

Price: £65.76/$109
Get it from: **www.tokyoflash.com**

Time telling became far too easy with the invention of the digital watch, so Tokyo Flash decided to take it to the next level. Even though the word funky hasn't been used seriously since the mid-1970s, these watches definitely come under that banner. Sporting a luminous blue, red or green design, these HAL-inspired displays do look pretty amazing.

The very outer ring tells you the hour by whatever block is missing and the ring inside tells you how many minutes have passed by the number of dashes inside. If you are an international businessman who needs to know what time the Stock Exchange is opening in New York or London, the two inner rings give you the option of setting a different time zone. Touchscreen technology will let you effortlessly set the date, the time or an alarm, and it does that part very effectively.

Build quality isn't the best. When putting it on, the metal face fell out of the plastic strap, so be gentle. The plastic feels a little bit cheap for what you're paying but what you're paying for is to be different. These watches are pretty daft but at the same time, great fun, so if you're prepared to spend a week getting to grips with telling time again, then go ahead! We might just stick to analogue, though.

Verdict:

ON THE HORIZON

Putting the smart in smartphone tech

Nokia 808 Pureview

We all love a selfie, but this is going above and beyond! This phone from Nokia boasts a frankly ridiculous 41MP camera, which takes in five times more light than the average smartphone camera.

Samsung Simband

The future of health could be a smart device on your wrist. This open-source technology measures heart rate, blood pressure and even lets people know if their heartbeat is irregular.

Get in touch

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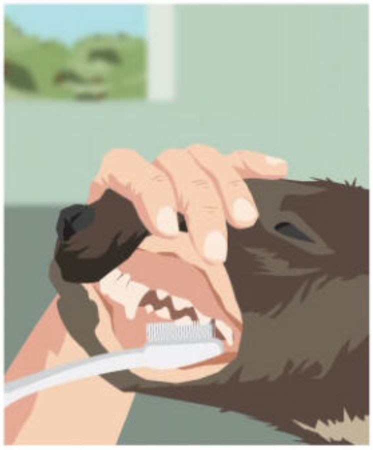
How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

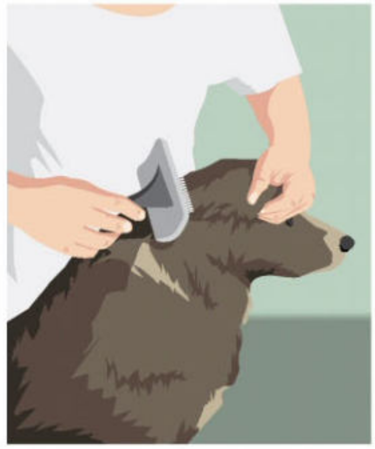
Pamper your pooch

Show your four-legged friends some love with these top grooming tips



1 Doggy dental

Avoid bad dog breath by giving their teeth a regular clean. Buy a specially designed brush along with some canine toothpaste. This comes in delicious flavours like chicken and beef and isn't harmful if swallowed. Gently put one hand beneath their muzzle to keep their mouth shut, then lift their upper lip. Brush carefully and keep around the gum line before doing the same for the bottom set. The ideal time is after a walk when they'll be tired.

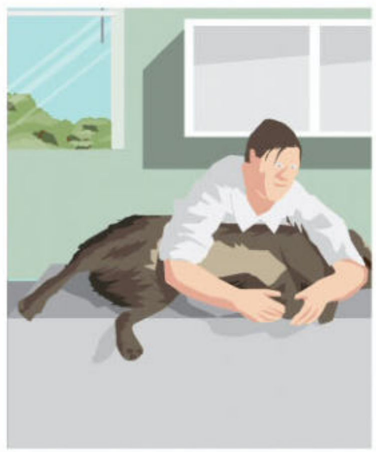


2 Brushing up

The coat can get tangled and matted, so a good brush will keep it glossy and clean. Begin at the head, brushing extremely gently in long, continuous strokes. Use a short-bristled, soft brush. Move onto the neck ruffs, then comb the forelegs before brushing the underbelly. You have to be more careful here as it is very a sensitive area. Next, brush all along its back and finally, the tail. Brush the hind legs and your dog should be lovely and smooth.

3 Bath time

Make sure you have everything you need close at hand, including a towel, shampoo, brush and treats to keep your pet happy! Use a heavy enough tub to not tip over should they try to escape and fill it with lukewarm water, enough to reach your pooch's chest. Gently work the pet shampoo into a lather, taking care not to get any in the eyes or ears. Once you've washed all the suds away, wrap them up in a towel and rub them down all over.



4 Trimming dog's nails

If the claws get too long, they can become uncomfortable. The best method is to lay your pet on a table and stand on the opposite side to the nails you're clipping. Reach over with your forearm gently on its neck, with one hand holding the paw and the other holding the clippers. Cut swiftly but carefully. The quick is a reddish part of the claw. Be sure to cut a few millimetres away from this, or your pet will begin to bleed.

5 Using eye drops

Your pet may get ill and the vet will tell you that it needs eye drops. If you find eye drops traumatic, think how awful it must be for animals! Ensure your pet is calm and relaxed, then sit them between your legs. Gently hold them under the chin and tilt their head back. Use your little finger to pull back the eyelid and administer the drops. Allow them to spread then release your pet before starting on the next eye. It's normal for them to paw their eye afterward but always consult a vet if their eyes get red.

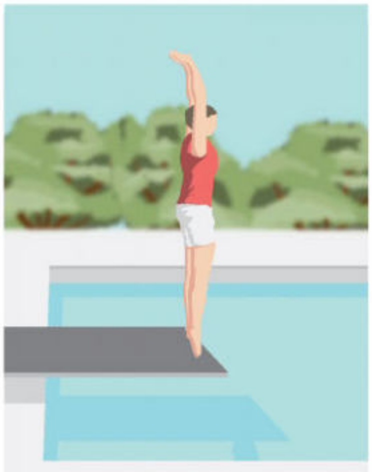
In summary...

Grooming is essential for pets' health and happiness, but patience is key. Animals likely won't enjoy baths or having their nails clipped, but as long as you are gentle with them, they will begin to learn the routine through reward-based training. If your pet gets agitated, the best thing to do is wait and let them calm down before continuing.

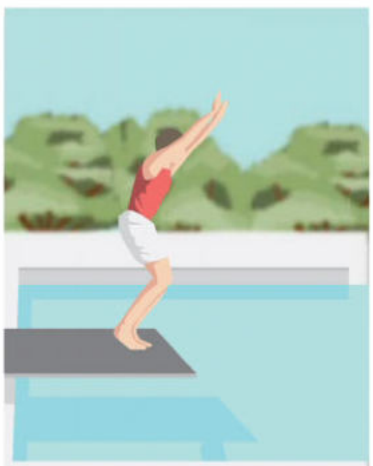
NEXT ISSUE
– Go fishing
– Make barista-style coffee

Perform a swallow dive

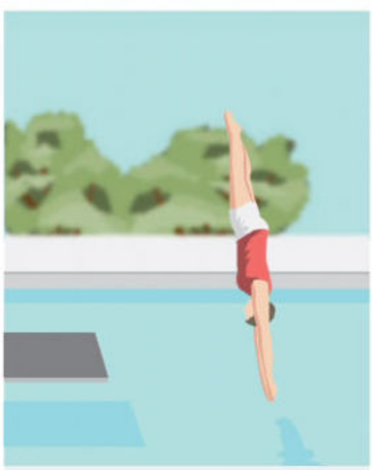
Unleash your inner Tom Daley and pull off the perfect dive



1 Find the edge
Walk to the edge of the diving board or pool and stand with your legs together. Place your toes just over the edge and curl them to provide yourself with the grip to properly push off from the edge. Bend your knees and hold your arms straight above your head, placing your palms together so your arms and body form a tall, narrow triangle. Push your head forward and down so you're looking directly at the water below you.



2 Take a leap
In one rapid, explosive movement, push yourself up and forward by falling forward slightly then extending your legs. For shallower water, make sure you fall slightly longer to travel further, but if you want to go deeper, leap quicker to achieve a higher elevation. Arc your body so your fingers are the first things that will enter the water. Try not to over or under rotate your body, which would result in either a sore stomach or back.



3 Entry into the water
Once your fingers have entered the water, keep them together and push outward in a breaststroke motion to propel yourself through the water. Straighten your body and keep your legs together throughout, pointing your toes to make your body as straight as possible. As your head submerges, breathe out through your nose to keep water out. Swim back to the surface where you hopefully won't be met by a panel of judges holding scores out of ten.

In summary...
The perfect swallow dive is all in the preparation. If you've got a good starting position and push off, your body should naturally arc, then straighten. Once in the air, remember to keep your arms and legs together and you should be the star of the pool.

QUICK QUIZ

Time to rack your brains with a quiz on the mag you've just read. A lucky winner will win an awesome Airfix Sherman model!

Answer the questions below and then enter online at **www.howitworksdaily.com**

1 How long did it take to build the Sydney Opera House?

2 The Americans had the armoured Sherman tank, but what was the name of its Russian equivalent in World War II?

3 What temperature is the hottest lava on Earth (in °C)?

4 What type of cells are mitochondria in?

5 How far away is the Sun from Earth (in km)?

6 How many tomatoes (in kg/m^2) can a hydroponic plot produce in a year?

7 How many computer processors does it take to simulate one second of human brain activity?

8 What does the abbreviation 'ODEON' stand for?

9 What is the world's fastest supercomputer (as of 2014)?

10 What years mark the Iron Age in Europe?

ISSUE 60 ANSWERS
1. Abdomen **2.** HAL **3.** 38.9km (24.2mi) **4.** 1928 **5.** Permian Extinction **6.** Bear Grylls **7.** Swedish 1m telescope **8.** The Red Baron **9.** Serotonin **10.** 1968

INBOX
Speak your mind...

Get in touch

Want to see your letters on this page? Send them to...

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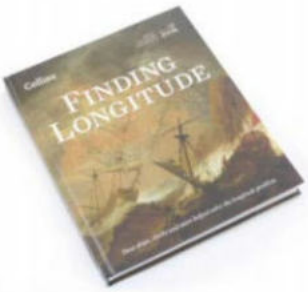
WIN!

We enjoy reading your letters every month, so keep us entertained by sending in your questions and views on what you like or don't like about the mag. You may even bag an awesome prize for your efforts!

AMAZING PRIZE FOR NEXT ISSUE'S LETTER OF THE MONTH!



FINDING LONGITUDE!

Next issue's star letter will win a copy of *Finding Longitude*, the official publication of the National Maritime Museum's exhibition 'Ships, Clocks And Stars: The Quest For Longitude', with photographs from the collection.

Letter of the Month

Will we run out of helium?

Dear HIW,
Your article in issue 60 on next-generation airships coincided with the arrival of a deflating party balloon in my garden. The connection, of course, is helium, abundant in the universe, but scarce on Earth. Is it sensible to use such a rare resource for trivial party celebrations? It cools the magnets in MRI scanners, is used in manufacturing microchips, deep-sea divers rely on it and airships require lots of it for lift. A few balloons at a party might not seem to threaten the world's shrinking reserves of helium, but how sad it would be if, some time in the near future, a seriously injured person can't be given an MRI scan to check for potentially life-threatening internal bleeding?
Alan Thomas

The most famous use of helium is for balloons and, of course, giving people high-pitched squeaky voices, but it is also, as you correctly say, used for many much more important things. We contacted David Smith, professor of Physics and Astronomy at the University of Southampton for the answer. "The problem is that helium is sufficiently light so at room temperature on the surface of the Earth, it has an escape velocity and will eventually leave the atmosphere for space," he says. "The helium atoms we have are alpha particles emitted during radioactive decay, which have slowed down and gained electrons. As radioactivity isn't that common to get usable quantities, you need to collect helium from a lot of rock. So I suspect the answer to the question of whether we are running out of helium is the same as the question: are we running out of petrol? In principle, yes, we are going to run out but there are lots of things we could do to increase the amount we can extract."

Will balloons be a thing of the past in a helium-scarce future?

© Alamy

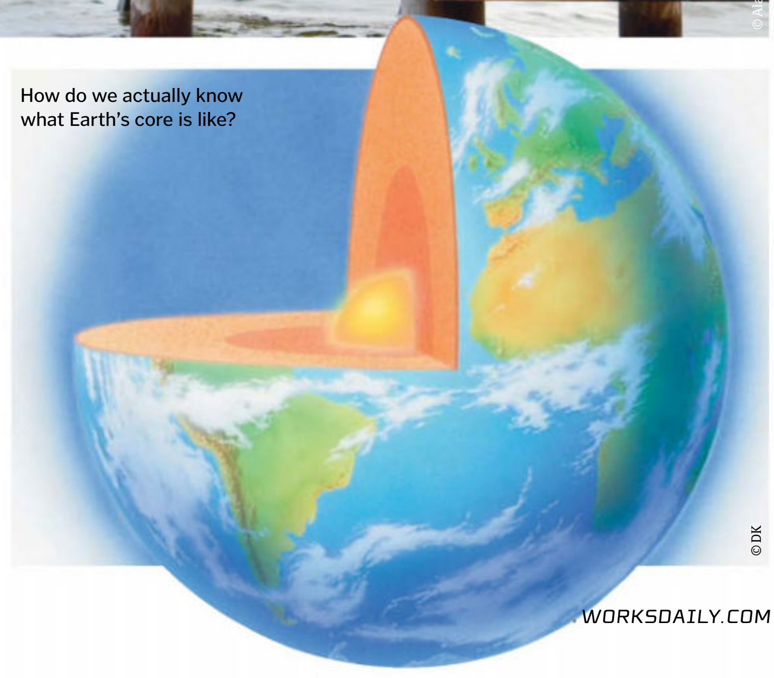
Inside the Earth

Dear HIW,
While revising for my chemistry exam I notice it claimed: 'Tectonic plates move very slowly. Global positioning satellites track their movements.' This must be very difficult as surely from the extremely high height that the satellites are orbiting, if it is pointing just one degree off the measurement, it could be metres if not kilometres out? I then started thinking how the centre of the Earth is located. The Earth isn't a sphere, let alone a smooth one, so how is the centre calculated?
Tom

Since the 1970s the Earth's tectonic plates have been measured by GPS satellites using a technique known as geodesy, which uses mathematical equations to understand and measure the environment. It works by repeatedly measuring distances between specific points to see if there has been any movement. They are so accurate that the fact they are in space doesn't affect the precision at all.

As for your second question, yes, the Earth isn't quite a sphere (it's been most accurately described as an ellipsoid) but this doesn't affect the search for the core. The centre is calculated by seismic waves. These P and S waves travel through solid and liquid matter differently and by using seismographs, geophysicists can determine what the mantle and core of the world are like, as well as finding the exact centre.

How do we actually know what Earth's core is like?



© DK

"They are so accurate that the fact that they are in space doesn't affect the precision"

New pair of genes

Hi HIW,
I was pooling over some ideas for a report on hereditary traits and genetics today and have a question: You know that when an X and a Y chromosome are joined, you get a male infant, and when an X and an X chromosome join together, you get a female infant. What happens when you get a Y and a Y chromosome joined together? I heard that it was called a virgin birth or something?
Edward

You are right, males have one X chromosome and one Y while female's are both of the X variety. If an X sperm fertilises the egg, the child will be female, and if Y, male. As a female is always X, there can never be a fertilised egg that has a YY chromosome pair. It's just not biologically possible. If YY conditions were somehow created, the cell would still not be able to function. A virgin birth is a form of asexual reproduction known as parthenogenesis and is not related to YY chromosomes. Known to occur in insects, fish, amphibians, reptiles and birds, but there are no known cases of it in mammals.


Your child's gender is all down to the Xs and the Ys


Every sperm cell has a completely unique set of data

© Getty

Biology class

Dear HIW,
My wife first brought your magazine to me when I was in hospital in January 2013 and I have been hooked ever since, so much so I have subscribed some time ago. My wife and my father-in-law are always sneaking a peek at my latest edition.

I would like to know the answer to the following question: there are millions of sperm cells with only one sperm cell fertilising the egg, if another sperm cell, say sperm cell B, fertilised the egg instead of sperm cell A (both from the same male), would we still have the same characteristics? This has puzzled me since Biology at high school.
Fraser MacFarlane BSc.

Thank you very much Fraser! We're glad our mag helped you through your hospital visit. Every sperm has different data stored within it so the person wouldn't be the same if another sperm cell had fertilised the egg. It has also been shown that even identical twins have subtle genetic differences! One more quick fact, did you know each sperm has around 37.5 megabytes of data within it?

What's happening on... Twitter?

We love to hear from **How It Works'** dedicated followers. Here we pick a few tweets that caught our eye this month...

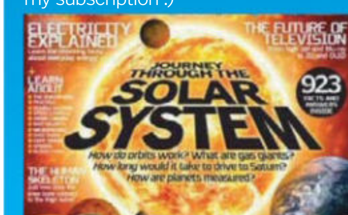
Nattie
@Nat__moores
I LOVE **@HowItWorksmag** – sinkholes, light speed, life in the boreal forest, science of happiness, quantum mechanics, Chernobyl. Best mag ever!

Matt Lathan
@slicks1812
I would like to say your **Book Of Incredible History** proved a valuable resource on my recent Roman themed cub camp :-)

plotloser
@plotloser
The Robot world cup??? http://bit.ly/V4BErb"bit.ly/V4BErb

Tom R
@blockswitch
I have all of my **@HowItWorksmags** in date order in a big box.

Tamara Taylor
@MrsT4math
Real-world applications galore in **How It Works** magazine. I just purchased my subscription :)



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